A. Vilstrup.

JOURNAL OF THE A·I·E·E·

AUGUST 1928

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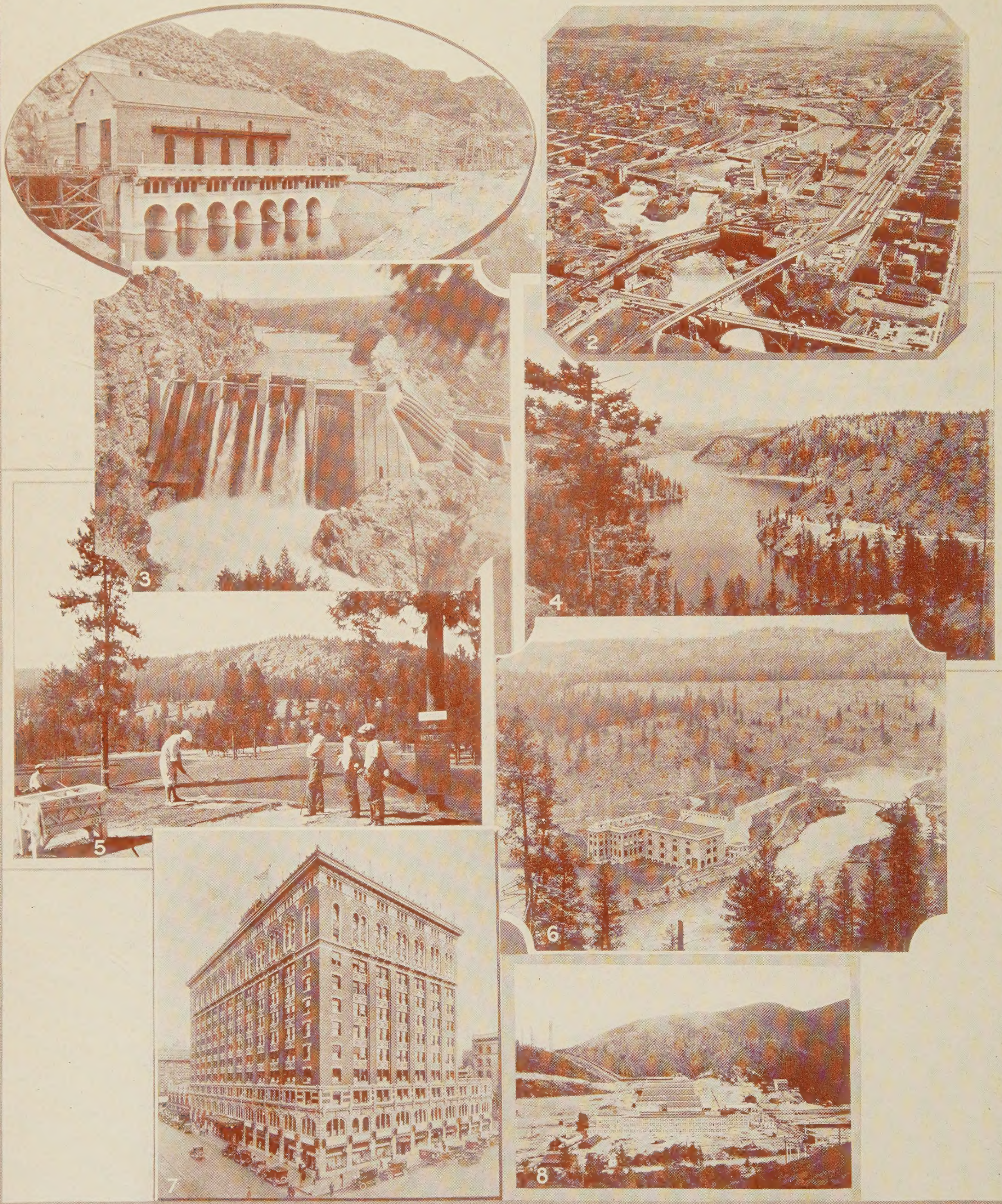
PUBLISHED MONTHLY BY THE
AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 WEST 39TH ST· NEW YORK CITY

ACIFIC COAST CONVENTION, SPOKANE, AUGUST 28-31

PACIFIC COAST CONVENTION
VIEWS IN AND AROUND SPOKANE



1. Chelon Station
2. Airplane View of Spokane
3. Long Lake Station
4 Scenic Drive along Lake Coeur d'Alene
5. Spokane Country Club Golf Course
6. Little Falls Station
7. The Davenport Hotel—Convention Headquarters
8. Electrolytic Zinc Plant, at Kellogg, Idaho

JOURNAL

OF THE

American Institute of Electrical Engineers

PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
33 West 39th Street, New York

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(The Journal of the A. I. E. E. is indexed in Industrial Arts Index.)

MEETINGS

of the

American Institute of Electrical Engineers

PACIFIC COAST CONVENTION, Spokane, Washington (August 28-31, 1928)

ATLANTA REGIONAL MEETING, Southern District No. 4 (October 29-31, 1928)

JOURNAL OF THE A. I. E. E.

Devoted to the Advancement of the Theory and Practise of Electrical Engineering and the Allied Arts and Sciences

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Vol. XLVII AUGUST, 1928 Number 8

Obligations of A. I. E. E. Sections To Public and Civil Relations*

This title naturally suggests a discussion of ways and means of making most effective contact with civic problems and of the duty of engineers to apply their special talents on matters of public welfare.

The conferences of the last two years showed that many such contacts are already made in an organized way. Engineers in general seem to appreciate their civic obligations, though the vast majority of them do not express this appreciation in vigorous action. Much of the discussion stresses the importance of getting prominent speakers to address engineering meetings and emphasizes the desirability of having such speakers reach the public through the radio and the press. This was the major substance of resolutions presented by the special committee on the subject at last year's conference, which resolutions were adopted by the Directors, and the Sections are now charged with making them effective.

These resolutions are excellent and should be carried out as one means of helping toward the desired goal. I am in full sympathy with this effort and also with every move looking toward the cooperation of engineers on matters of general community interest as well as engineering interest.

I am wondering, however, if there isn't more that we can do or if we might not put the greater emphasis on a further activity. I am going to take some liberties with the title assigned me and dwell on *how the Sections can make the engineer more effective in his public relations.*

We have been told that one of the ways to win from the public a higher regard for our profession is for us to interpret the engineering world to the public mind. Herein, I believe, lies our biggest opportunity. The very need for interpretation suggests the engineer's weakness because of which much of his work has missed the world's acclaim. He is not a boaster or an advertiser. His training has made him abhor these. But yet he complains because of lack of recognition. (Fortunately the plaintive voice is weakening perceptibly.)

We must recognize that Mr. Average Citizen is a moderately superficial thinker and if we want to catch and hold his eye and ear we must use methods that he will readily understand. We must learn to lay aside engineering language at times.

*Talk before Sections Delegates Conference, Denver, Colo., June 25, 1928.

Let me try to illustrate what I have in mind. Let us suppose that an engineer has laid out a splendid bit of highway illumination between two cities. Engineers would probably be much interested in a description of the work presented at an engineering society meeting. The description would very likely deal almost entirely in foot candles, lumens, light distribution, glare, construction details, etc., and the resultant discussion would probably deal with reflectors, special lamps, etc., etc. The suggestion that this installation would be a splendid subject for presentation before the chamber of commerce of a town would most likely meet with no support because the public interest in an engineer's paper would not be sufficient.

However, let us suppose that this engineer sees far beyond his slide rule and that he would tell a story dealing with the importance of this particular highway to the towns it connects, leading up somewhat historically perhaps to the economic value of the highway and how this would be increased if the road could be used safely at night. Suppose he tells a very human story of the efforts to provide satisfactory illumination for this purpose, and how the idea was sold to the townships along the way that had to provide budget allowances for it. Then in closing suppose he emphasizes how the installation was made so it would add to, rather than detract from the natural beauty of the scenery, indicating that engineers know the social value of beauty.

Do you think that such an engineering story would be rejected by any chamber of commerce? And if presented, do you think the audience would consider that particular engineer as a man whose interests are "solely technical" and apart from the human run of life? Would not the audience catch a glimpse of the real part that the engineer plays in "the general scheme of things?"

Of course, it is not every engineering accomplishment that has such a direct public relation as has highway illumination, but the example, I hope, brings out the point I am trying to make. If engineers, even when talking to fellow engineers in their own societies, will dwell more on the human purpose of their work, without, however, omitting the essential technical phases, the popular conception of the engineer as one more interested in things than in human beings will soon disappear and the public will pay more sympathetic attention to his work. Also, the effort to see his own

work at longer range will give the engineer a better perspective and may fill him with a new enthusiasm over the social value of it. Incidentally, the engineer himself and his audience may form the habit of the larger perspective in their thinking.

Is not now the time for us to take advantage of the attention being given to the engineering profession because of the prominence of one of its outstanding members? Let us take our place where all educated men and women of the nation should take theirs, as leaders and not as voices crying for recognition.

How can the Sections best serve this end?

Primarily by utilizing every opportunity to interpret engineering in human terms. To do this most effectively the members should be urged to practise public speaking. Occasional debates would help toward this and would also add interest to a Section's program. And how about contests between Sections? Civic problems should have a fairly frequent place on the program and "prominent speakers" only on rare occasions. Prominent speakers usually speak *at* their listeners, while the greatest and most lasting good results from speaking *with* them.

The members of the Section should be encouraged to address civic bodies, whenever an opportunity is presented for the discussion of a subject of civic interest on which engineers should have special knowledge, but engineering information should be presented in the form of intensely interesting stories rather than as recitals of cold facts.

Of course, engineers should participate with interest in public affairs, but they should make that participation interesting to the public.

Along with this, the Sections have a wonderful opportunity to help in the broader development of the young engineering graduates, who are located in their communities and who have been taught the value of early professional society contact. These youngsters can be inspired by visions of service offered through the profession, or their youthful ardor can be dampened by emphasis on the hard work and long hours that alone lead to success. Which is the better to emphasize? What is our obligation to these engineers of the immediate future?

In conclusion, if engineers are really the helpers and friends of mankind that we are often credited with being, let us attune our thoughts and modes of expression to the rest of mankind and in our search for the Royal Road to Success and Happiness we will probably find the way sprinkled with flowers of appreciation from our fellows in quite sufficient abundance.

R. F. SCHUCHARDT

Some Leaders of the A. I. E. E.

Cary T. Hutchinson, Manager of the Institute 1895-1898, and Vice-President 1898-1900, is a native of St. Louis, Missouri. He was graduated from Washington University there in 1886 with a degree of Ph. D. obtaining a like degree from Johns Hopkins University 1889 in which University he was later elected a Fellow 1888-1889.

It was in 1889-1891 that Doctor Hutchinson actively began his professional career in the railway departments of the Sprague Electric Railway Company and the Edison General Electric Company. In 1892 the consulting firm of Sprague, Duncan and Hutchinson was organized with Frank J. Sprague and Louis Duncan, Professor of Electrical Engineering at Johns Hopkins University and by this firm, the first electric locomotive in the United States was designed and built for the North American Company for use on the Chicago terminals. These consultants also served the B. & O. Railroad in connection with electrifications in Baltimore as well as a number of other traction lines in that same section. Since then, in an independent capacity, Doctor Hutchinson has been consulting engineer for many prominent concerns.

During 1902-1903 he was appointed chairman of a commission to design and construct an electric lighting system for the City of New York, and with Doctor Louis Duncan, served the First Rapid Transit Commission, (1902-1904) in a consulting capacity. In 1907-1908 Doctor Hutchinson designed and built the electric traction system for the Cascade Tunnel Section of the Great Northern Railway Company in Washington. Carrying his electrification work on as member of the engineering staff reporting on a superpower system for the Eastern District of the United States, in 1920-1921 he was in charge of the Commission's railway electrification work, at the same time acting in like capacity for the Illinois Central Railway Company in connection with its Chicago Terminals. In 1926 investigations and reports on electrification of the Main Central Railroad from Portland to Bangor were made by Doctor Hutchinson. For one year he was in charge of the Electrical Engineering Department at Johns Hopkins University. He was the first secretary of the National Research Council and of Engineering Foundation, and is also an active member of The American Society of Mechanical Engineers and other representative engineering and scientific bodies. Doctor Hutchinson is also a prolific technical writer. Some of his papers which have come before the Institute are *The Protection of Secondary Circuits in Fire Risks* (1899); *Series Electric Traction* (1892); *The Relation of Energy to Motor Capacity and Schedule Speed in the Moving of Trains by Electricity* (1902); *Conditions Governing the Rise of Temperature of Electric Railway Motors in Service* (1903); *The Electric System of the Cascade Tunnel of the Great Northern Railway* (1909) and *The Economical Capacity of a Combined Hydroelectric and Steam Power Plant* (1914). Besides these, many of his articles, some in collaboration with such men as Louis Duncan, Gilbert Wilkes and Henry Rowland have been published in the *Electrical World*, the *Philosophical Magazine*, the *Electrical Engineer* and other technical publications as well as many by himself alone.

Economy in the Choice of Line Voltages
and Conductor Sizes for Transmission Lines

BY E. A. LOEW*
Member, A. I. E. E.

***Synopsis.**—Fundamentally, the choice of line conductors and of line voltage for any transmission line is based upon economic law. While the law is simple enough, its application is quite involved. A mathematical statement of the law as applied to transmission line design was presented in a previous paper[1] but the utility of the conclusions there reached was somewhat limited by the lack of suitable constants. The present paper provides suitable constants through which the application of the theory previously developed is extended to all types of transmission line conductors now in general use in America The paper concludes with a set of calculated curves for which the most economical line voltage and the most economical conductor area can be read off for a transmission line project of any assumed length and transmitting any assumed amount of power. The results obtained from the curves are found to agree very well with good engineering practise.*

* * * * *

Introduction

It is well known that the most economical conductor area to be used in any transmission line project is a function of the load to be transmitted, and that once the voltage is fixed, the required conductor area may readily be found by the aid of Kelvin's law. It is also known, though not so generally appreciated, that the over-all economy in transmission line practise is likewise a function of the line voltage used. Accordingly, since the size of the most suitable conductor can be determined properly only after the voltage is fixed, and since, initially, the voltage to be used is presumably unknown, the problem becomes a complex and difficult one to solve. The solution is usually obtained by the trial-and-error method. By this method, separate calculations are made for each of several standard line voltages. From among the several results thus found, the engineer, in an attempt to select the most economical design, then makes his choice. The method is indirect, time consuming, difficult of application, and unscientific.

A direct method[1,2] which eliminates much of the uncertainty of the older method and greatly simplifies the work of making these calculations, once suitable data are available, has recently been offered. It is the purpose of the present paper to show how the method may be applied to the general problem of transmitting any assumed load over a line of any assumed length by the use of any one of the available kinds of aluminum or copper conductors. Curves are presented from which the most economical voltage, and the corresponding most economical conductor size, may be selected at once. Necessarily, the results are given for certain assumed average conditions of costs, types of construction, et cetera; but it is the writer's belief that for most cases, they will serve very well. Where it seems desirable to do so, corrections may readily be made to fit new circumstances more exactly.

Theoretical Background

The theoretical basis for the present discussion is found in the paper indicated by Reference 1. There the writers showed that a correct interpretation of Kelvin's law required that the value of the energy annually wasted as line loss be set equal to the annual charge against all items of conductor cost, line cost, and terminal equipment cost, whose values vary with either conductor area or line voltage. Accordingly, in order to make a solution of the problem possible, each of these items of cost must be expressed as a function of either conductor area or line voltage. In terms of the symbols given below, the four items mentioned may be written for a three-phase line as follows:

1. Dollars annual value of line loss $= b\,\rho\, l\, A\, I^2 \div d_s^2$
2. Dollars annual charge against line conductors $= 3\,B\,p_1\,l\,d_s^2 \div c^2$
3. Dollars annual charge against that portion of tower cost which varies with the conductor area $= 0.01\,p_2\,l\,M\,d_s^2$
4. Dollars annual charge against that portion of terminal appara us cost which varies with conductor area $= 0.01\,p_3\,k_{11}\,d_s^2$

The symbols used have the following meanings:

I = R. m. s. current per line conductor in amperes.
d_s = Outside diameter of stranded conductor in inch units.
c = $d_s \div d$, a constant (approximately) for a particular type of conductor.
d = Diameter of the equivalent solid rod in inch units.
A = Dollars selling price of one kw-hr. at receiver low-tension bars.
l = Length of line in feet.
ρ = Resistivity of conductor material in ohms per mil-foot.
b = A constant whose value depends upon the ratio $d_s \div d$, and upon the units used.

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*Prof. of Elec. Engg., University of Washington.

Presented at the Pacific Coast Convention of the A. I. E. E., Spokane, Wash., Aug. 28-31, 1928.

1. *Transmission Line Design—II. The Line of Maximum Economy*, by F. K. Kirsten and E. A. Loew, A. I. E. E. Journal, Dec. 1925, p. 1356.
2. Electrical Power Transmission. McGraw-Hill Co., by E. A. Loew.

B = Dollars cost of one foot of line conductor per million circular mils.

p_1, p_2 and p_3 The rates of interest and depreciation applicable to line conductors, to tower structures or supports, and to terminal equipment, respectively, all expressed as whole numbers.

M = Tower constant [see Equation (**51**), Reference 1.]

k_{11} = Terminal apparatus constant.
= $3\, k_{11}'\, U^2$

k_{11}' = A constant defined by the equation, cost = $k_{11}'\, E^2 + k_{12}$, representing the cost of terminal equipment as a function of the line voltage.

U = A constant relating conductor diameter and voltage [see Equation (**22**) Reference 1.]
= $[38 + 200\,(m_0\,\delta\, r - 0.30)] \times 10^3$ approximately.

m_0 = Roughness factor in Peek's law of the corona.

δ = Air density factor in Peek's law of the corona.

r = The assumed ratio of operating voltage to critical disruptive voltage (usually between 0.8 and 0.9)

By equating item 1 to the sum of items 2, 3 and 4, a mathematical statement of a modified form of Kelvin's law is made available. This equation solved for the line current yields;

$$I = d_s^2 \left[\frac{1}{\rho\ A} \left(\frac{0.03\, B\, p_1}{b\, c^2} + \frac{0.01\, p_2\, M}{b} + \frac{0.01\, p_3\, k_{11}}{b\, l} \right) \right]^{1/2} \qquad (\mathbf{1})$$

Upon multiplying the left hand member of (**1**) by $3\, E_n \cos\theta$ and multiplying the right hand member by the equivalent value, $3\, d_s\, U \cos\theta$, [see Equation (**62**) reference 1], the left-hand member becomes equal to 1000 times the r. m. s. kilowatts transmitted. Solving the resulting equation for the cable diameter yields

$$d_s = \frac{10\ (\text{r. m. s. kilowatts})^{1/3}}{J^{1/6}\,(F + G + H)^{1/6}} \qquad (\mathbf{2})$$

The new symbols here introduced are defined below.

E_n = the transmission line voltage to neutral.

$$J = \frac{U^2 \cos^2\theta}{\rho\, A} \qquad (\mathbf{3})$$

$$F = \frac{0.27\, B\, p_1}{b\, c^2} \qquad (\mathbf{4})$$

$$G = \frac{0.09\, p_2\, M}{b} \qquad (\mathbf{5})$$

$$H = \frac{5.12 \times 10^{-5}\, p_3\, k_{11}'\, U^2}{b\, L} \qquad (\mathbf{6})$$

Where L is the length of the line in miles.

Evaluation of Constants

Since the purpose of the present investigation is to evaluate the economic conductor sizes and line voltages for a wide range of loads and lengths of line, and for the available kinds of conductors, such values are assigned to the constants as seen to fit average conditions best. For the convenience of the reader, the values used will be tabulated.

Only three of the constants in the foregoing equations require a word of special explanation. These are the constants U, G and k_{11}'.

The constant U relates the conductor diameter to the line voltage through the medium of Peek's law of the corona; it is the constant which alone makes a mathematical solution of the problem in hand possible. Since the corona voltage is a function of the distance between conductors as supported on the towers or poles, so is the value of U dependent upon the distance of separation. Accordingly, the value of U will depend somewhat upon the type of towers and the conductor spacings used as well as upon the values assumed for the roughness factor, the air density factor, and the percentage of the critical disruptive voltage at which the line is to operate.

The constant G of Equation (**5**) is found by expressing the cost of line towers as a function of voltage. It is very difficult to evaluate G accurately, but fortunately, it is a constant whose influence upon the choice of voltage and conductor size is usually of less importance than is that of either of the other terms of equation (**2**).

The constant H, Equation (**6**), is a very important factor in lines under 100 mi. long. It represents the annual outlay chargeable to terminal equipment, per unit length of line. To evaluate H for any transmitted load requires that k_{11}' be estimated for each load assumed. Investigation discloses that for a given load transmitted over a line, the cost of all terminal equipment, housing, and wiring can be expressed as a function of the line voltage by an equation of the form

$$\text{Cost} = k_{11}'\, E^n + k_{12}$$

where E is the line voltage and k_{11}' and k_{12} are constants. If the range of voltages considered lies between 88 kv. and 220 kv., the above equation is found to fit the actual costs quite closely over the entire range, when the value 2 is assigned to n. Thus, the constant k_{11}' is the slope of the straight line which represents terminal apparatus and housing costs as a function of [line voltage]^2.

Evidently k_{11}' varies somewhat with the amount of power that the equipment must handle, as well as with the degree of complexity of the substation layout. Values of k_{11}' have been estimated for various loads up to 100,000 kw. and for three types of station wiring (see Table 1) varying from a simple circuit layout in column 1 to the double-bus type of structure in column 3.

The unit prices of conductors are given by the symbol B, which represents the cost in dollars per circular inch-foot of stranded cable. Where bi-metallic or hemp-core conductors are used the unit cost is still given per circular inch-foot of the conducting material, but the unit cost in such cases is higher than for the

TABLE I

VALUES OF k_{11}' FOR VARIOUS LOADS

Type of wiring*	25,000 kw.	50,000 kw.	75,000 kw.	100,000 kw.
No. 1.....	7.0×10^{-6}	7.5×10^{-6}	8.0×10^{-6}	8.5×10^{-6}
No. 2.....	10.6×10^{-6}	11.1×10^{-6}	11.6×10^{-6}	12.1×10^{-6}
No. 3.....	13.8×10^{-6}	14.3×10^{-6}	14.8×10^{-6}	15.3×10^{-6}

*No. 1 represents the simplest type of station layout, while No. 3 represents the most complex type.

TABLE II

VALUES OF CONSTANTS USED

Item	Stranded Aluminum		Stranded Copper		
	All-Aluminum	Steel-Core	Usual Strand	Rope Core	Hollow-Core
C	1.15	1.23	1.15	1.35	1.35
B	0.302	0.314	0.545	0.578	0.63
A	0.004	0.004	0.004	0.004	0.004
p	18.0	18.0	10.8	10.8	10.8
b	35.7×10^{-6}	40.5×10^{-6}	35.7×10^{-6}	48.9×10^{-6}	48.9×10^{-6}
U	118,500	118,500	118,500	118,500	118,500
k_{11}'	As per type 2, Table I, depending upon load				
G	9,000	16,000	18,000	13,000	13,000
p_1	12	12	10	10	10
p_3	12	12	12	12	12
$J^{1/6}$	73.5	73.5	80.0	80.0	80.0
F	16,200	13,900	31,000	17,500	19,500

TABLE III

CORRECTION FACTORS FOR VALUES OF A

A	Correction factor for e and d_s
\$0.001	0.79
0.002	0.89
0.003	0.95
0.004	1.00
0.005	1.04
0.006	1.07
0.007	1.10

ordinary stranded cable, since it must include the extra cost of the core, et cetera.

The selling price per kw-hr. of energy at the low-tension bus is assumed at \$0.004 in all of the calculated results herein given. The values of voltage and conductor size corresponding to any other assumed values of A may be found, however, by multiplying the figures obtained from the curves by the factors of Table 3.

Table 2 shows the values of the various constants which were used in calculating the data for the curves of Figs. 1, 2 and 3.

Curves of Most Economical Voltage

The results of calculations based on the foregoing theory, and the constants of Tables I and II, are given in the curves of Figs. 1, 2 and 3. The curves for stranded all-aluminum cables differ only slightly from those for steel reinforced aluminum conductors and are therefore not given separately here.

To illustrate the use of the curves, assume the following projects:

(a) A hydroelectric plant having an installed capacity of 80,000 kv-a., and delivering its output at 90 per cent power factor and 60 per cent load factor over two similar lines each 100 mi. long.

(b) A proposed development having an estimated ultimate capacity of 440,000 kw. when fully developed. It is assumed that an average load factor of 60 per cent will be maintained, and that the entire plant output will be delivered to a market 200 mi. away.

The r. m. s. kilowatt per line for project (a) are 21,600. Reference to Fig. 2 shows that for stranded-copper cable, this output requires a 110-kv. line. Since the load to be transmitted calls for 110 kw. almost exactly, no adjustment as to conductor size need be made. By the equation of Fig. 2, the cable area required is approximately $17.9 \times (110)^2 = 216{,}000$ cir. mils. This corresponds very closely to No. 0000 cable, whose area is 212,000 cir. mils. Accordingly, No. 0000 stranded copper cable would be entirely suitable.

Upon investigating the possibilities of steel-core

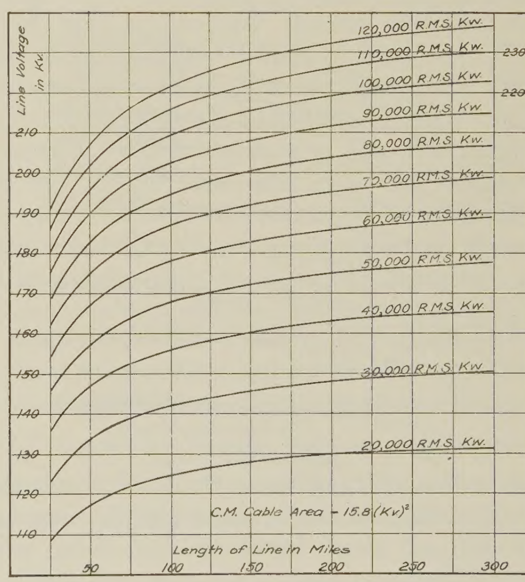

Fig. 1—Most Economical Voltages for Steel-Core Aluminum Lines

aluminum cable, it is found that a load of nearly 22,000 kw. requires 132 kv. as the nearest standard voltage. The corresponding cable area is $15.8 \times (132)^2 = 276{,}000$ cir. mil. The nearest standard cable has an area of 266,800 cir. mils of aluminum. If 110 kv. were used with aluminum, in order to maintain approximately the

same losses, the next larger size of cable would probably be chosen; namely 336,400-cir. mils or No. 0000 copper equivalent.

Of course the final choice of conductor and voltage would be made only after comparing total line costs for the two types of conductors and after giving due consideration to the matter of voltage standardization for the system as a whole, regulation, load limits, et cetera.

Next, consider the ultimate development of project (b). The number of lines to be used will be determined to a large extent by consideration other than those of Kelvin's law. Yet, in general,—and in the interest of economy,—the number of lines should be kept low. The use of only two lines for such a huge block of power would probable not be proposed seriously by anyone. As a matter of fact, the curves show that for two lines only, the voltages required are in excess of 220 kv. for all conductors with the exception of stranded copper cable. We shall therefore consider the possibilities of three and four lines. Using the same value of load factor as before, the r.m.s. kilowatts of load per line are 88,000 and 66,000 for the three- and four-line cases respectively. From the curves it is apparent that both assumptions call for lines having voltages in excess of 154 kv. for all of the available types of conductors. Thus, in either case, the voltage selected would probably be 220 kv.

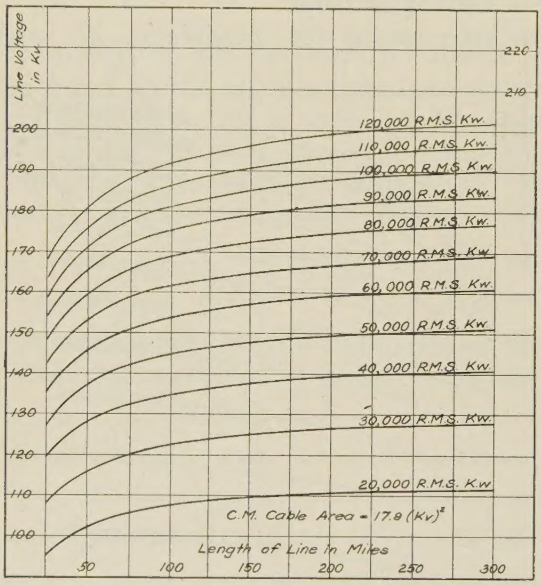

FIG. 2—MOST ECONOMICAL VOLTAGES FOR STRANDED-COPPER LINES

This voltage would virtually rule out stranded-copper conductor from consideration, since the curves of Fig. 2 show that even for the three-line assumption, the economical voltage is only 180 kv. The 220-kv. stranded-copper line with conductors of sufficient size to prevent corona would probably have more carrying capacity than required, and would be uneconomical.

The steel-core aluminum line fits conditions much better. The three-line assumption would call for 220 kv., requiring $15.8 \times (220)^2 = 765{,}000$ cir. mils of aluminum. The nearest standard cable is 795,000 cir. mils, having an outside diameter of 1.093 in. The use of four lines would probably require the same voltage and the same size conductors, but would provide additional line capacity.

Hollow-core and hemp-core copper conductors require 195 kv. and 175 kv. for the three- and four-line

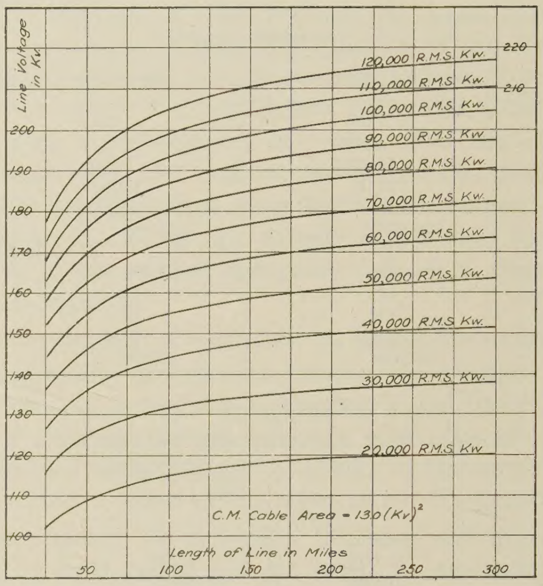

FIG. 3—MOST ECONOMICAL VOLTAGES FOR HOLLOW-CORE AND HEMP-CORE COPPER

cases, respectively. In either case, a 220-kv. line would be demanded, utilizing conductors of approximately $13 \times (220)^2 = 630{,}000$ cir mils.

The above conclusions are based upon the assumption of energy loss valued at four mils per kw-hr. If two mils be used instead for project (b), the various economical voltages already found would be lowered to 89 per cent of the values given. The use of stranded copper cable and 154-kv. transmission would then come into consideration as a possible solution.

PHOSPHORESCENT LIGHT ILLUMINATES NOVEL SIGN

Under the above title in *Signs of the Times* for June, 1928, is described a unique system of illumination for advertising displays which is being demonstrated and introduced into this country by a British firm, Luminad, Ltd., of London. The process is said to consist of preparing bills and other subjects with special coloring pigments or inks and subjecting these articles at night to a harmless form of invisible ultraviolet radiation. Under the action of the rays the inks and pigments employed become richly self-luminous and emit a brilliant phosphorescent light, causing the design on the bill face to stand out is stereoscopic effect.

Abridgment of

Residual Air and Moisture in Impregnated Paper Insulation–II

BY J. B. WHITEHEAD[1], Fellow, A. I. E. E.
W. B. KOUWENHOVEN[2], Member, A. I. E. E.
and F. HAMBURGER, Jr.[3], Associate, A. I. E. E.

Introduction

IN an earlier paper[4] has been described a series of studies of the influence of residual air and moisture in impregnated paper insulation, such as used in high-voltage cables. Briefly, the method used was to prepare samples in groups of three, to dry them in accordance with a standard program, to impregnate them at different values of absolute air pressure, and to study the resulting influence on the power-factor—voltage curves. This gave information as to the influence of residual air. Separate studies were made of the dielectric absorption and residual conductivity of the paper before and after impregnation for different states of initial dryness. These studies, in conjunction with the resulting power-factor—voltage curves, gave information as to the influence of moisture.

One of the conspicuous results of these studies was the relatively small importance of the air pressure at which impregnation took place on the resulting power-factor—voltage curves. Between 1 and 10 cm. Hg., absolute pressure of evacuation, there was little or no change in the shape of these curves. Moreover, they were exceptionally good as compared with the curves of commercial cables, being perfectly flat up to 300 volts per mil working stress, and for temperatures up to 50 deg. cent. It is only at impregnating pressures above 25 cm. Hg. that the typical rising break in the power-factor—voltage curve begins to be evident.

Another result of interest is the relatively small importance of a variation in the moisture content on the shape of the power-factor curve. Moisture content is a relative term, and the foregoing statement refers to variation as regards moisture in a condition which must be described as fairly dry.

Comparison of Drying Processes

In view of these results it appeared desirable to study the relative importance of the different drying processes. The inspection of many factories in this country and abroad has shown an extremely wide variation in practise in this regard. The extremes noted were a preliminary drying process at atmospheric pressure, followed by six days under temperature and vacuum, on the one hand, and absence of all preliminary drying, immediate submersion in compound and twenty-four hours heating at reduced pressure on the other. It is obvious, therefore, that either some cables are much better than others, or that some manufacturers are wasting time and energy. The following studies were undertaken in the hopes of throwing some light on these questions.

In our studies of the relative importance of different periods of initial drying and impregnation, test samples were prepared in groups of three each, with final conductivities in the neighborhood of 30, 60, and 120 cm. galvanometer deflection respectively. The authors have considered each group of three samples as a unit, treating and drying them together so that the final average values of conductivity are close to the figures mentioned. Specimens having the above characteristics were subjected in turn to evacuation processes represented by 5, 2, 1, and 2 mm. Hg. absolute pressure. Throughout this program, the final conductivity at the end of twenty-four hours was in general taken as a basis of comparison. Three other groups were also included in this program of tests. No one of these received any preliminary drying and therefore all contained in the neighborhood of 8 per cent to 10 per cent of moisture. Two of these groups, Nos. 28 and 29, were placed immediately in the evacuating chamber and the pressure reduced to 2 mm. Hg. the temperature being held at 105 deg. cent. and the conductivities observed at the end of twelve and twenty-four hours respectively. The third group No. 36 was placed immediately in the impregnating chamber, without preliminary drying and the chamber immediately filled with compound. The pressure was reduced to 3 mm. Hg., the temperature adjusted to 105 deg. cent., and both maintained constant for twenty-four hours.

Change of Power Factor with Time

Those accustomed to measuring the power factor of cables and impregnated paper in general have frequently noted that the power factor changes with the time. For the most part, these reported changes are gradual, but in a few cases very rapid changes have been reported; as, for example, an absolute change of 40 per cent within a few minutes. In our own experiments we have noted changes of a few per cent in observed values from day to day, but for the most part they have not been sufficiently great to require special study nor to affect the general conclusions we have drawn from our studies. The most serious changes of

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4. A. I. E. E. Trans. Quarterly, 1928, Vol. 47, No. 1, p. 314.

Presented at the Regional Meeting of the A. I. E. E., District No. 2, Baltimore, Md., April 17-20, 1928. Complete copies upon request.

this type we have noted are associated with poorly impregnated specimens at high temperatures. In these cases ascending and descending power-factor—voltage curves are separated and variations with time have been noted. The paper describes the experiments performed and the results of further investigation in this direction.

The detailed results of the work described in this abridgment may be found in the original paper. These studies were carried out in the School of Engineering, The Johns Hopkins University, at the request and with the support of the subcommittee on Impregnated Paper Insulated Cable Research, of the National Electric Light Association, D. W. Roper, Chairman. For the continued interest and hearty cooperation of the members of the Committee the authors extend their grateful acknowledgment.

Conclusions

Taken in conjunction with the earlier paper our present results would seem to indicate the following:

1. For the drying of cable paper before impregnation, preliminary drying before vacuum treatment is unnecessary except, perhaps, as a convenient method of driving off a large part of the water always found in cable paper.

2. Drying at reduced air pressure is very much more rapid for the same drying temperature than drying in the open. At a drying temperature of 105 deg. cent. at atmospheric pressure, and in a steady draft of air, a steady condition of the paper as regards dryness is reached only after from two to three days. The same condition can be reached if dried at 105 deg. cent in a vacuum of from 2 to 5 mm. Hg. absolute pressure, in from 12 to 24 hours. It is not possible, however, to reach this same condition of dryness over any length of time if the evacuation pressures are above 5 mm. Hg. It is probable that a continuous replacement of water vapor by dry air in the vacuum chamber would alter this conclusion; however, when drying at atmospheric pressure the great value of the draft of air is evident. Higher values of the temperature result in further improvement as regards dryness and conductivity.

3. Initially undried and unevacuated paper placed immediately in the impregnating chamber and then subjected to heating to 105 deg. cent. and evacuation pressure of 3 mm. Hg. for 24 hours, results in an insulation having remarkably good properties. At temperatures up to 40 or 50 deg. the power-factor—voltage curves are flat and of value of the same order of magnitude as those pertaining to specimens that are far more carefully dried. In the upper range of temperatures the power-factor curves have abnormal shapes, although they do not show values unduly high.

4. For thoroughly dried paper impregnated at 105 deg. cent. and pressures of 2 mm., 5 cm., and 30 cm., there are no sharp changes in power factor following abrupt changes of voltage.

5. Prolonged runs under voltage cause no appreciable changes in the properties of thoroughly dried and impregnated insulation (dried at 2 mm. Hg. and impregnated up to 15 cm. Hg.). For insulation impregnated at higher pressures there is a pronounced improvement as a result of the continued application of voltage. We attribute this to the slow consumption of the entrained air in ionization and its combination with the compound, with resulting decrease in ionization losses.

6. The improvement in power factor noted in the foregoing paragraph is accompanied by a noticeable drying or stiffening of the paper. We attribute this to the production of solid decomposition products of the oil, and thus have the suggestion that the generation of X-wax, or similar product, is associated with a decrease in power factor. Whether this would continue through long periods is a question for further study.

7. Poorly impregnated cable insulation may show excellent power-factor curves indicating low ionization for temperatures up to 40 or 50 deg. cent. and yet not have permanent characteristics. Examples are group 36, impregnated without preliminary drying and showing the curves of Fig. 3, and the several curves around 40 deg. of group 37. In such cases, a temperature cycle may result in a marked change of characteristics. At higher temperatures there are often marked differences from the characteristics of insulation which is thoroughly dried and impregnated.

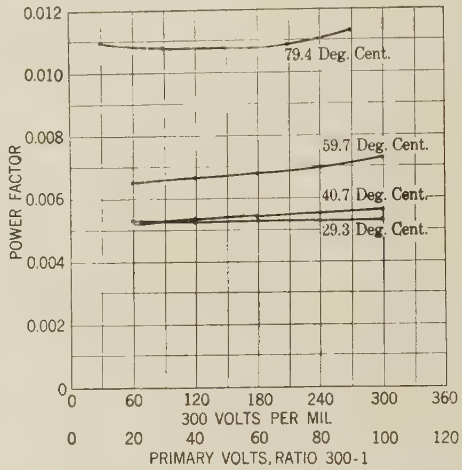

Fig. 3—Power Factor—Voltage Curves

Specimens 36A, 36B, 36C. Conductor diameter = 1.0 in. Insulation = 0.10 in. wall. No preliminary drying

8. A general survey of these and foregoing studies indicates the relative unimportance of air pressure of impregnation within a fairly wide range say up to 15 cm., and even up to 30 cm., if the paper is vacuum dried. Excellent power-factor—voltage curves may be found throughout this range. We conclude therefore that the sharply rising curves and rapid changes in power factor, often noticed in commercial cables are due to relatively large and extended areas of entrapped air or gases, resulting either from imperfect impregnation, distortion in handling, or temperature expansion of lead sheath.

Abridgment of

Rocky River Hydroelectric Development

Of The Connecticut Light and Power Company

BY E. J. AMBERG[1]

Associate, A. I. E. E.

Synopsis.—*This paper describes the Rocky River hydroelectric development of The Connecticut Light and Power Company, near New Milford, Connecticut, which is a storage development for regulating the Housatonic River below New Milford.*

There are no sites on the main river suitable for a large storage reservoir. It was therefore necessary to select a site on a tributary, the Rocky River. The run-off from the natural drainage area of the reservoir basin furnishes only a part of the water required to fill the reservoir, making it necessary to pump the balance from the Housatonic River against a maximum head of 240 ft. This is the first large application of pumped storage in the United States, which accounts for the general interest shown in the Rocky River development.

* * * * *

The Rocky River hydroelectric development of The Connecticut Light and Power Company has created considerable interest among technical as well as non-technical men as a project for regulating the flow of the Housatonic River below New Milford, Connecticut. Briefly, the development consists of a storage reservoir created on Rocky River, a tributary of the Housatonic, with a power and pumping plant on the Housatonic River, the power and pumping plant being connected by a single penstock with the reservoir.

The Rocky River basin is located north of Danbury and west of the Housatonic River, and the site of the development is approximately 1½ mi. by state highway from the nearest railroad station at New Milford. The basin has a drainage area of approximately 40 sq. mi., eight and one-third of which are covered by the storage lake. The Rocky River flows through marshy flats which form the bottom of the reservoir, to a point 2½ mi. from the junction of the Rocky River with the Housatonic, wherein Rocky River falls about 200 ft. over a rocky bed. The shores of the reservoir are for the most part steep and rocky, rising to elevations of from 500 to 1000 ft.

The unusual feature of this development lies in the fact that the drainage area of the reservoir basin will supply only about 1.5 billion cu. ft. of water in an average year, while the useful capacity of the reservoir is 5.9 billion cu. ft. All water above the natural run-off required to fill the reservoir must be pumped from the Housatonic River against a head varying from 200 to 230 ft. While considerable excess hydro energy will be available for pumping, the studies and investigations for this development are all based on using secondary steam energy for pumping, to be generated at the Devon steam station of The Connecticut Light and Power Company and transmitted to Rocky River.

The Rocky River reservoir may be likened to a large storage battery. Charging the battery is accomplished by two 8100-hp. centrifugal pumps delivering water to the reservoir. The battery is discharged by means of the 30,000-kv-a. generating unit delivering primary hydro energy. The efficiency of this storage battery for changing secondary steam energy into primary hydro energy is 61 per cent; this includes all losses from the 66,000-volt bus at the Devon Steam Station through the pumping units into the reservoir and back through the generating unit to the 66,000-volt Rocky River bus. In other words, for every 100 kw-hr. supplied by the Devon Steam Station in filling the reservoir, 61 kw-hr. are delivered by the Rocky River generating unit when the water is drawn out again. We must not, however, overlook the fact that below the Rocky River plant there is an additional total average head of 191 ft. available, of which 71 ft. is efficiently developed at Stevenson. If the head at Stevenson is added, then for every 100 kw-hr. of steam energy, 79 kw-hr. of hydro energy are returned. If the total head from Rocky River to tide-water is added, 111 kw-hr. of hydro energy could be obtained from every 100 kw-hr. of steam energy used in pumping.

Before going into a more detailed description of the Rocky River project, it is desirable to review briefly two factors which are essential to understand the basis upon which Rocky River has been developed. These two factors are: the hydrology of the Housatonic River, and the general character of the system load curves of The Connecticut Light and Power Company.

It is generally known that the rivers in the eastern part of the country have a very irregular flow, unless some natural or artificial means exists for regulation. The Housatonic River, with which we are concerned, had no means of regulation; the stream flow shows very wide variations, as can be seen from Fig. 3, showing hydrographs and duration flow curves for a typical wet, average, and dry year. From the hydrographs it is quite evident that the only period of the year when any reliance can be placed on the river flow is in the Springtime. The rest of the year the flow is quite irregular. While frequently a somewhat larger flow may be ex-

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pected in the Fall, there is no certainty of it, as shown for the dry year, where the low water condition continued right to the end of the year. With the river plants at Stevenson and Bulls Bridge operated in conjunction with the Rocky River storage plant the 24-hr. firm power of the hydro system is 11,000 kw. Fig. 4

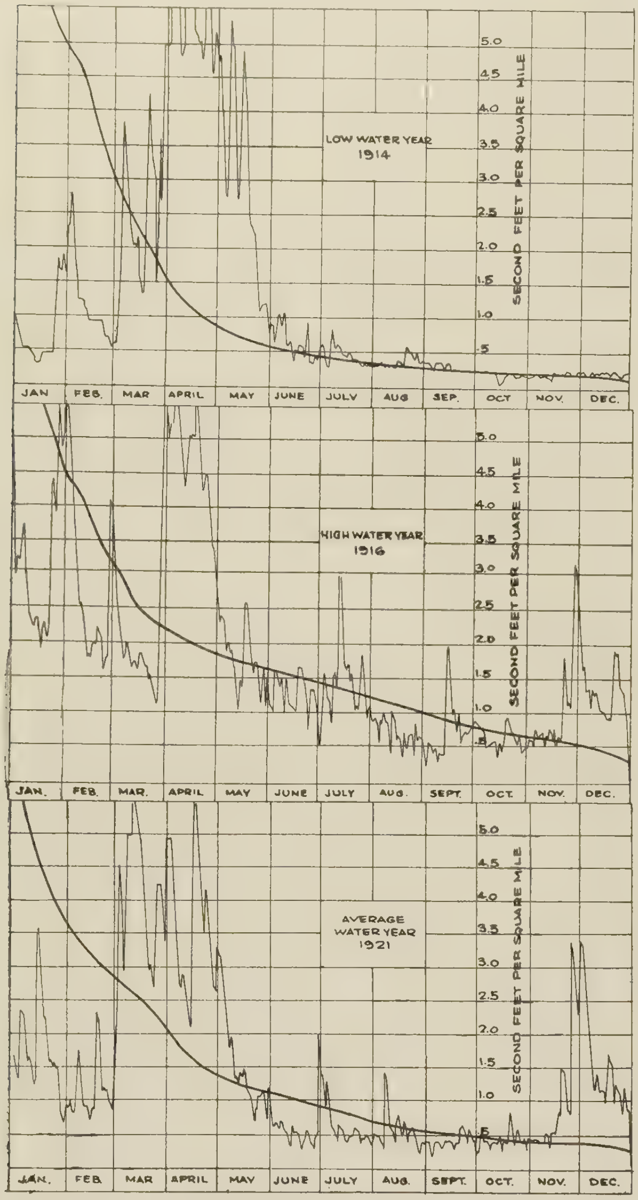

Fig. 3—Hydrographs of the Housatonic River

Showing hydrographs and superimposed flow duration curves for a low water year, a high water year, and an average water year

shows the unregulated power duration curves for a typical dry, wet, and average year, limited by the installed capacities of the Stevenson and Bulls Bridge stations which together total 26,000 kw. The regulated 24-hr. firm power of 11,000 kw. obtained by the addition of Rocky River is also shown. The respective areas between the 11,000-kw. regulated firm power and the power duration curves represent the energy which has to be furnished from storage. The amount required in each year varies considerably, being 9,500,000 kw-hr. in the wet year and 39,900,000 kw-hr. in the dry year. Of these amounts, 78 per cent is produced by the Rocky River station and the balance at Stevenson, generated from the water released from Rocky River station.

By applying the 24-hr. firm power of 11,000 kw. to the upper half of the load curve, as shown in Fig. 5, curve 1, the total installed hydro capacity of 50,000 kw. can be used as firm capacity. Before regulation by Rocky River, the combined firm capacity of the Stevenson and Bulls Bridge stations was only 10,000 kw., although the installed capacity was 26,000 kw. Therefore, by installing a 24,000-kw. generating unit in the Rocky River station and by regulating the river the firm hydro capacity has been increased by 40,000 kw.

To obtain maximum benefit from such a storage development it is necessary to apply it to that part of the load requiring the smallest number of kilowatt

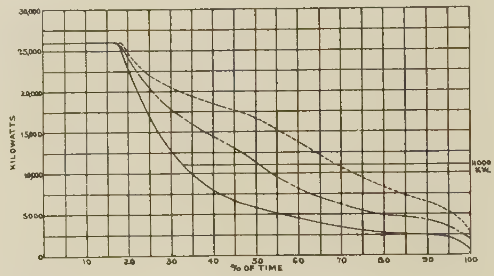

Fig. 4—Power Duration Curves for the Combined Output of Bulls Bridge and Stevenson Stations Without Regulation by Rocky River Development

Typical low water year 1914 . . . .
Typical high water year 1916 . . . .
Typical average water year 1921 . . . .

	Drainage area	Net head in ft.	Kw. per cu. ft. per sec.	Installed capacity
Bulls Bridge	782 sq. mi.	104	6.27	7,200 kw.
Stevenson	1510 sq. mi.	71	4.40	18,750 kw.
				26,000 kw. approx.
Rocky River	35 sq. mi.	214.2 av.		
		Power—	15.55	
		Pumping	25.35	

Regulation by Rocky River development to produce 11,000 kw. firm 24-hr. capacity, expressed in kw-hr.

	Low water year	High water year	Av. water year
Rocky River output	31,100,000 kw-hr.	7,400,000 kw-hr.	17,400,000 kw-hr.
[1]Stevenson output	8,800,000 kw-hr.	2,100,000 kw-hr.	4,900,000 kw-hr.
Total output	39,900,000 kw-hr.	9,500,000 kw-hr.	22,300,000 kw-hr.

1. Generated at Stevenson on water discharged from Rocky River

hours. This brings us to the second factor, the load curves.

When plotting system loads in the form of an annual duration load curve we will find that there is a decided peak. The reasons for this pronounced peak on the duration load curves vary; in metropolitan districts the short-time lighting peaks are largely responsible; on systems like The Connecticut Light and Power Company, where there are no short-time peaks of any extent, the seasonable changes in load are responsible. In the latter case, what appears as a very short-time

peak on the duration load curve is the result of the 9-hr. day loads of the maximum days.

It can readily be seen that a different method of applying the hydro power is necessary in the two cases of peak load. In the first case of the metropolitan area, a weekly, possibly even daily, storage capacity will take care of the individual peaks, permitting the utilization of the river for actual demand without any seasonal storage. On the other hand, to take care of peak conditions on a system like that of The Connecticut Light and Power Company, seasonal storage in addition to weekly pondage is required. This seasonal storage is being provided in our case by the construction of the Rocky River storage reservoir.

Fig. 5 shows two annual duration load curves; curve 1

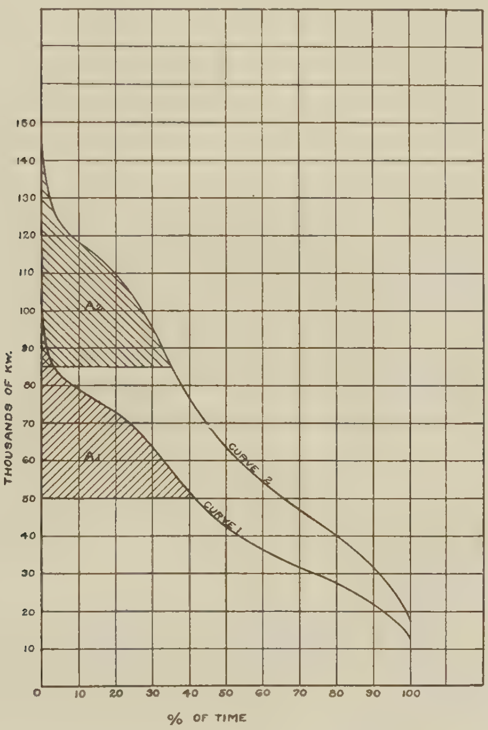

Fig. 5—Load Duration Curves

	Curve No. 1	Curve No. 2
Max. kw-hr	100,000	150,000
Load factor	47.3%	47.3%
Hydro kw	50,000	65,000
Increase		15,000
Hydro load factor	17.2%	13.2%

Hydro area A_1 = hydro area A_2

represents the present approximate combined load of The Connecticut Light and Power Company and associated companies, while curve 2 shows the expected combined load for the year 1931. The upper half of load curve 1 and load curve 2, for that matter, contains only 18.2 per cent of the total kw-hr.; the load factor of this part of the load is 17.2 per cent. The advantage of applying the hydro generating capacity to the peak of the load and the steam generating capacity to the base of the load is quite evident from a study of this load curve. Assuming that the total load has increased 50 per cent as indicated by curve 2 on Fig. 5, the same number of hydro kilowatt-hours represented by area A 2 would permit a firm hydro capacity of 65,000 kw. as against 50,000 kw. firm capacity of curve 1; or 15,000 kw. firm capacity could be installed without increasing the storage facilities. Additional capacity can often be installed at a low cost per kilowatt in existing plants, thus lowering the average unit cost per kilowatt of hydro capacity.

Aside from the features discussed above, hydro plants have another great advantage in that they provide standby capacity which can be made available in a fraction of the time required at a steam station, because to get up steam and warm up a turbine requires time unless boilers are kept in service and excess turbine capacity is kept on the line to take care of sudden load demands.

With the means of regulating the stream flow below Rocky River it will be possible to develop the full head on this section of the river, which will then produce a total 24-hr. firm power of approximately 23,000 kw.

With an assumed load factor of 23 per cent it will be possible to increase the total installed hydro capacity to 100,000 kw. by developing the full head of the river between tide-water and Rocky River.

Description of the Rocky River Development

Reservoir and Dams. The storage reservoir or lake is about 10 mi. long and 1¾ mi. across at the widest part. It has a surface area of 8⅓ sq. mi. and a shore line of approximately 60 mi. The creation of a lake of this size made it necessary to abandon and relocate highways and homes. Approximately 31 mi. of highway were abandoned and 9¼ mi. of new and relocated highways were built. Six cemeteries were relocated. Outside of several summer colonies located around the four ponds included in the basin, only 35 families with permanent residences were affected by the construction of this reservoir, which is an unusually small number considering the area covered. The bottom of the reservoir was for the most part swampy ground, and 4500 acres were covered with woods.

The main dam is located across Rocky River at a point about one mile above its junction with the Housatonic River. It is an earth filled dam with a core wall. The lower part of this core wall consists of a two-foot concrete section. On top of this concrete section was placed a six-inch Wakefield core wall (timber). Fig. 6, showing a cross-section and plan of the dam, gives a better idea of its construction than a lengthy, detailed description.

To take care of some low points in the rim of the basin five smaller dams were necessary. Two of the dams are near Danbury. Both are earth dams of the same general design as the main dam. The other three dams are located near Lanesville. The north and south Lanesville dams are constructed of concrete. The so-called Lanesville Gap was closed by an earth dam similar in design to the main dam. Seamy rock

at the west end of this dam presented considerable difficulties in obtaining a tight job.

The crest of the main dam and the Danbury dikes is at elevation 442 ft., or 12 ft. above the present normal maximum reservoir level at elevation 430 ft.

The crest of the dike at the Lanesville Gap is at elevation 440 ft., or 2 ft. lower than the crest of the main dam. This dike is located in a cove which practically eliminates all wave action, which accounts for the 2 ft. lower crest.

The present crest of the concrete section of the South Lanesville dam is at elevation 432 ft. and of the North Lanesville dam at elevation 431 ft. Each of these concrete dams is so designed that the concrete sections can later be raised four feet at a nominal cost. This construction would be done in order to raise the level in the reservoir from 430 ft. to 435 ft., which would add approximately one billion cubic feet to the reservoir.

Intake. The canal leading from the reservoir to the intake was excavated for about 3300 ft. along the east bank of the valley. Terminating the dike in the side hill permitted the construction of a circular intake tower in the canal with only a short length of concrete conduit extending through the dike. A self-closing sliding Broome gate is located at the entrance to the concrete conduit in the tower and operated by electric hoist.

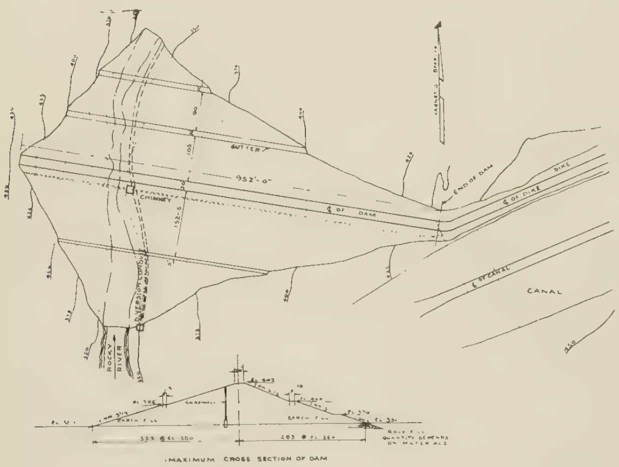

Fig. 6—Plan and Cross-Section of the Main Earth Dam

Penstock. The concrete conduit, having an inside diameter of 16 ft., extends only a short distance from the intake tower to the wood stave pipe line. This wood pipe line has an inside diameter of 15 ft. and extends for approximately 1007 ft. along the hillside. The wood pipe line joins a steel penstock *Y*-connection; one of the two branches is blanked off ready for a second penstock for the future unit, while the other extends a short distance to a Johnson differential surge tank. From the surge tank the penstock drops down the hillside to the power house. The inside diameter varies from 13 ft. to 11 ft. just outside the power house, where there is another *Y*-connection, one branch for the generating unit and the other for the two pumping units. Each branch has a Venturi section for measurement of flows. Fig. 7 shows the general layout of the penstock.

Power Station Building. The foundation rests on bedrock which was so close to the elevation desired that little rock had to be taken out or extra concrete put in. The south end of the building, referred to as the switch bay, is supported on reinforced concrete columns.

The power house superstructure is of structural steel framework and brick. Precast gypsum slabs provide the foundation for an asphalt built-up roof. All exterior trim of the building is of precast cement blocks.

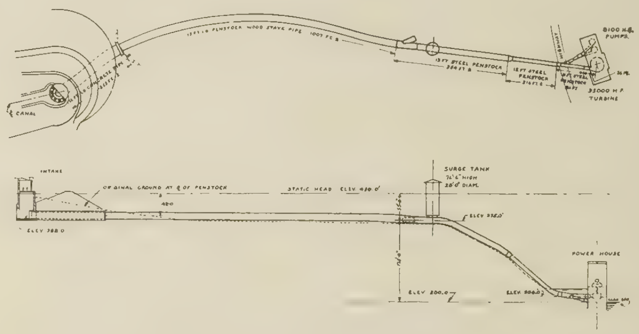

Fig. 7—Plan and Profile of the Pipe Line and Penstock

There are four floors in the switch bay with a control cable terminal room below the first floor. The first floor is the control room with the switchboard. The second floor contains the 13,200-volt pump motor bus and switching, and the third and fourth floors are used for the 4600-volt distribution bus and storage battery room.

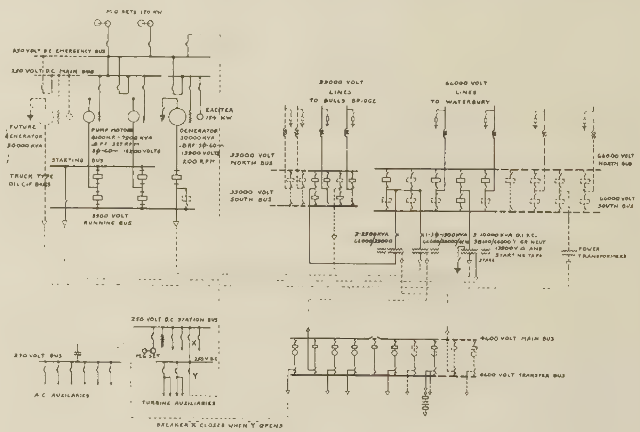

Fig. 8—Single-Line Wiring Diagram of Rocky River Plant

Hydraulic Equipment. The hydraulic equipment of the power station consists of one 33,300-hp. vertical shaft turbine and two 8100-hp. vertical shaft centrifugal pumps. A noteworthy feature of the turbine is the cylinder gate which replaces the more conventional Butterfly or Johnson valves for directly shutting off the flow of water to the turbine.

The centrifugal pumps, so far as the author knows, are

the largest in the United States. The pump specifications called for a rating of 112,500 gal. per min. (250 cu. ft. per sec.) delivered against a maximum head of 240 ft. In the discharge line of each pump is a hydraulic-cylinder-operated Dow pivot valve.

Electrical Equipment. The generator is of the standard vertical water-wheel type with shaft and exciter. It is rated at 30,000 kv-a., 80 per cent power factor, 13,900 volts, three-phase, 60-cycle, 200-rev. per min., with direct-connected exciter rated at 154 kw., 250 volts, compound wound with interpoles. The pump prime movers are vertical synchronous motors rated at 7900 kv-a., 80 per cent leading power factor, 13,200 volts (with voltage range of 5 per cent above or below) 3-phase, 60 cycle, 327 rev. per min. Pump motor and spare excitation are furnished by two motor-generator sets each consisting of a 150-kw., 1200-rev. per min., 250-volt, compound-wound d-c. generator with interpoles direct-connected to a 225-hp., 220-volt, three-phase 60-cycle, squirrel-cage induction motor.

Station and Substation Equipment. Under this heading there are five distinct groups:

a. 4600-volt indoor local distribution bus
b. 33,000-volt outdoor tie-in bus for Bulls Bridge station
c. 66,000-volt outdoor main station bus
d. 13,900-volt indoor bus for pumps
e. Station service busses.

A single-line wiring diagram, Fig. 8, shows the general arrangements.

The High-Speed Circuit Breaker in Service
on the Illinois Central Railroad

BY W. P. MONROE[1] and R. M. ALLEN[2]
Member, A. I. E. E. Non-member

***Synopsis.**—The purpose of this paper is to describe briefly the distribution system of the Illinois Central Suburban Electrification and to state considerations influencing the selection of high-speed circuit breakers for d-c. feeder and machine protection. The knowledge gained by nearly two years' operating experience with this system, which contains 98 high-speed circuit breakers, and the conclusions reached, are also presented.*

* * * * *

THE first large installation of high-voltage d-c. high-speed circuit breakers for railway service was placed in operation on the Chicago suburban electrification of the Illinois Central Railroad, in July, 1926. The reasons for the adoption of these circuit breakers for this electrification, and the results thus far obtained with them, may be of interest to those who are contemplating similar applications. With this idea in mind, the distribution system in general will first be described with special regard to those features influencing the selection of the high-speed breakers. A description of the installation and tests will then be given, and finally, the operating experience of twenty months service will be discussed.

Design Features of Distribution System[3]

The distribution system of this 1500-volt d-c. suburban electrification was designed to deliver current to the trains with the necessary voltage regulation, with economy in the use of copper, and with the utmost reliability. A simple system resulted consisting of seven substations conveniently spaced and feeding directly a catenary system without additional feeders paralleling the tracks. A satisfactory efficiency of distribution was obtained by the use of *tie stations* to connect the catenaries of all tracks together at various points, thus dividing the current among the catenaries over all tracks and utilizing the total copper to the best advantage.

The absence of feeders, other than the catenaries themselves and the substation connections thereto, is a factor in obtaining simplicity and in applying high-speed circuit breakers. It happened that the mechanical design of the catenary was very well suited to the conductivity requirements, this feature being partly due to the use of tie stations and partly due to the fairly close spacing of the substations.

The tie stations, besides increasing the distribution efficiency, divide the catenary system into short sections, each fed through its own circuit breakers. Because of the large number of sections and sectionalizing points of this design, remote control of the circuit breakers is necessary. The Illinois Central system makes use of supervisory control by which the power supervisor, from his desk, can open or close any circuit breaker on the system and receive indications of the opened or closed positions of these breakers at any time.

A simplified schematic diagram of the distribution system in the district having the heaviest traffic is shown in Fig. 1. It is of that portion of the system

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2. Power Supervisor, Illinois Central Railroad.
3. For a detailed description of the I. C. R. R. distribution system and other phases of this electrification, see series of articles in *General Electric Review*, April, 1927.

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928.

extending from the north terminus at Randolph Street to Brookdale Substation, 8.3 miles south. On every week-day over 560 electric trains pass through this district, the trains ranging from two to eight cars in length, the average car weighing 63 tons. The load factor, or ratio of average hour to maximum hour over 24 hr., is approximately 40 per cent for a typical week-day load.

The complete distribution system on a smaller scale is shown in Fig. 2.

Considerations Leading to the Selection of High-Speed Breakers for the Service

The reliability of the distribution system depends upon adequate protection from short circuits, overloads, and other electrical disturbances. Its availability, or freedom from service interruptions, depends upon the quick isolation from the rest of the system of a section directly affected by the fault without interfering with service on the neighboring sections.

An inspection of Fig. 1 shows that in the Illinois

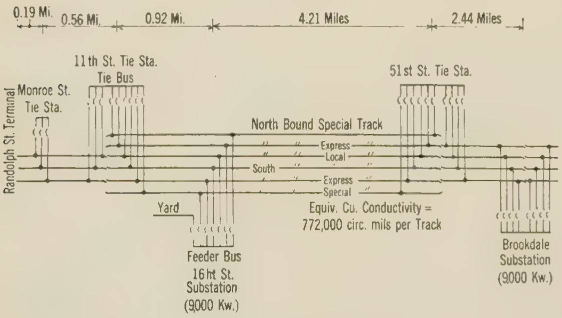

Fig. 1—Schematic Diagram of Portion of Distribution System

Central distribution system most of the sections of track are fed directly or indirectly through a large number of circuit breakers; and that if a short circuit occurs in one section, a number of other sections may be affected unless only the breakers feeding directly into the short circuited section open and isolate it. The circuit breakers, therefore, should have a high degree of selectivity in their operation.

They should also act at sufficiently high-speed to avoid serious burning of the catenary or train equipment.

They should be adapted to remote control since many of them will be in unattended stations and all must be under direct control of the power supervisor's office.

Their reliability should be such that they will not require very frequent maintenance attention.

The Commonwealth Edison Company of Chicago and affiliated Public Service Company of Northern Illinois own and operate the substations feeding the Illinois Central distribution system, and also own and maintain the feeder circuit breakers in the substations. The operation of these breakers, however, is of great importance to the railroad because they form a part of the distribution system and must act in conjunction with the tie station breakers. The Edison Company and railroad engineers, therefore, worked together in selecting the type of circuit breaker and protection scheme used in the substations.

A study of the merits of all proposed 1500-volt d-c. circuit breakers, including extensive factory tests, resulted in the selection of the General Electric type J R high-speed circuit breaker for the service, and this type is used in all section feeders at all substations and tie stations (Fig. 3.) They are also used in both positive

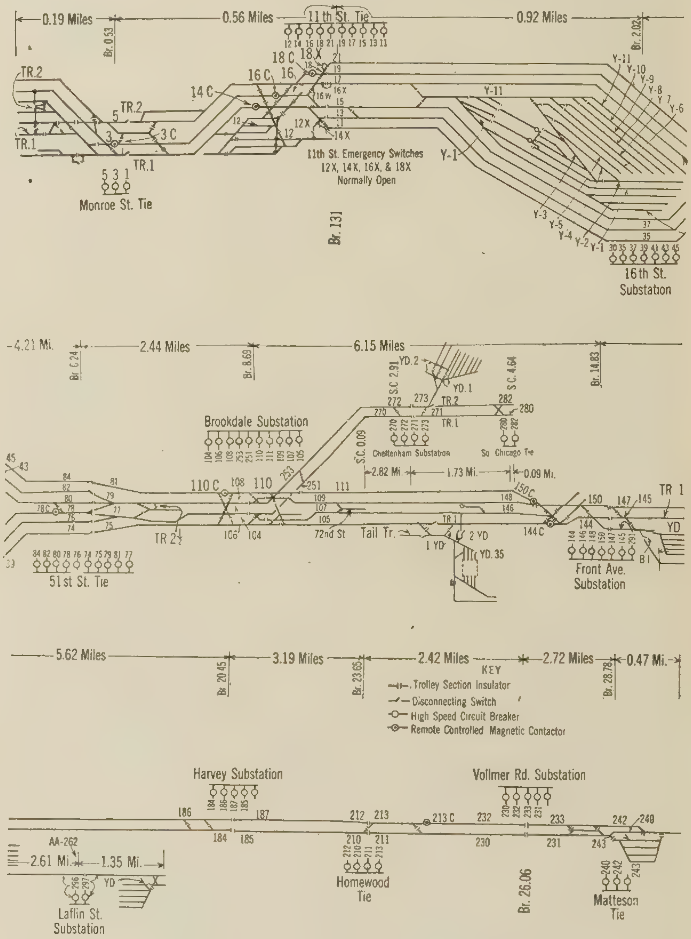

Fig. 2—Complete Scheme of Distribution on the Illinois Central Railroad

and negative leads of the synchronous converters in substations. The detailed theory of action of this breaker has been previously described before the Institute.[4]

Installation and Inauguration of Service

The most modern type of construction was used in the installation of the circuit breakers in both substations and tie stations. Each high-speed breaker is mounted on its own truck with control panel, and spare trucks with breakers are available so that repairing is made

4. *The High-Speed Circuit Breaker in Railway Feeder Networks,* by J. W. McNairy, Trans. A. I. E. E., Vol. XLV, 1926, p. 962.

easy by the removal of the bad order circuit breaker and truck to be repaired and replacing it with a spare truck containing a spare circuit breaker. The circuit breaker trucks can be interchanged readily in the tie stations and in the substations, but an attempt is made always to keep each breaker in the same feeder. Although most of the parts are interchangeable, a complete tie station breaker cannot be interchanged with a substation breaker, because the holding coil of the tie station breaker is energized from 1500 volts while that of the substation breaker is energized from the substation 125-volt d-c. supply.

Automatic reclosing features are a part of the control of the tie station breakers, but the closing

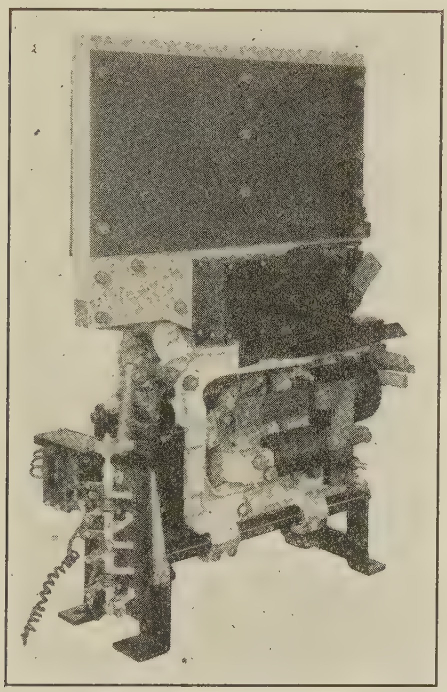

FIG. 3—HIGH-SPEED BREAKER UNMOUNTED

of substation feeder breakers is governed entirely by supervisory control. Both tie stations and substations are equipped with transfer buses so that in emergencies two or more sections can be fed through the same circuit breaker.

The calibration of the feeder circuit breakers was made at the factory. The settings of the tripping points, however, were precalculated by the railroad company's engineers, and the breakers were set accordingly during the installation. In order to make sure that the predetermined settings were right, a number of short circuit tests was made at the completion of the installation and when power was available at the d-c. buses of the substations. A test car was equipped so that short circuits could be applied at any point, and an oscillograph was installed in the car to record the short-circuit currents and time characteristics of the circuit breakers.

The first tests were made at the Homewood tie station, in an outlying district, where short circuits were applied to the catenary at a point very close to the tie station. It was found that the selectivity of the circuit breakers in isolating the fault was very satisfactory. Tests were also made at 11th Street tie station, one of the largest tie stations in the system, and in this case also the selectivity was satisfactory with the predetermined settings, but some minor adjustments were found to be necessary. Similar tests were made at the other tie stations and substations. In this way the system was "tuned up" for safe and correct operation of circuit breakers. In only a few cases was it deemed advisable to change the predetermined circuit breaker settings.

In the two-track district between Front Avenue and Harvey substations, there is no tie station, (see Fig. 2). It was found that the rate of current rise at one of the Front Avenue substation feeder breakers was not sufficient to open it when a short circuit was applied near the Harvey substation, although the Harvey substation end cleared satisfactorily. The short-circuit current in this case is limited to a maximum value of approximately 3500 amperes by the resistance of the line. The predetermined setting of the Front Avenue breakers was 4000 amperes, but it had to be reduced to 3500 amperes to insure protection. Since the breakers feeding the district south from Brookdale substation to Front Avenue substation, and those feeding north from Harvey substation to Front Avenue have the same feeding distance without tie stations, their settings were also lowered to 3500 amperes. Later, the manufacturers altered the design of the inductive shunt for these breakers, changing both resistance and inductance, so that the settings could be raised to 4000 amperes with ample protection. These circuit breakers with low settings are now all equipped with the new shunts and the settings readjusted to 4000 amperes accordingly. Since the accelerating current of a ten-car multiple unit train approaches 4000 amperes the setting at 4000 amperes (for straight overload) seems to be low to prevent circuit breaker openings from the useful load. Actually, the breakers are sometimes opened by the load, and as traffic increases, the openings will increase. It has always been the intention of the railroad to build a tie station in each of these districts when the traffic so demands.

These preliminary tests on the distribution system have proved the advisability, if not the necessity, of thoroughly trying out a distribution system of this kind before regular service is started. As a further precaution, when the I. C. R. R. electric suburban service was fully inaugurated in August, 1926, emergency operators were stationed in the most important tie stations during the rush hours to take care of any failure or faulty operation of the circuit breakers. The necessity for this latter precaution was not proved, however, since no serious troubles developed.

Results of Twenty Months Operating Experience

Since August 1926, the high-speed breakers have been in continuous service handling the dense traffic of the Illinois Central electrified suburban lines. During this period, there has been opportunity to observe their performance under varying conditions, and there are presented herewith brief comments on certain features of the actual operation in service of these high-speed breakers.

Advantages

The inductive shunt principle and directional characteristics of the high-speed circuit breakers make automatic isolation of trouble by selective operation simple and almost 100 per cent.

The high-speed operation reduces to a minimum the damage to train equipment and overhead. In fact, the burning is so slight that in most cases it is difficult to locate by inspection a traction motor which has flashed over. In no case has the damage by a single flashover been sufficient to necessitate taking a motor out of service.

With a lapping section insulator, such as is used on the Illinois Central, more or less burning is caused by a pantograph moving over a section insulator, one side of which is alive and the other side temporarily grounded by a short circuit or for some other reason. High-speed circuit breakers reduce this burning to a minimum. A recent communication from the Victorian Railways of Melbourne, Australia, which is in the process of changing to high-speed circuit breakers on their 1500-volt d-c. electrification, states that trouble from this cause has been considerably reduced thereby. Their report bears out the experience of the Illinois Central.

Care of the high-speed circuit breaker contracts has been found to be almost unnecessary, due to the secure manner in which they are held together magnetically, instead of relying on a spring and latch arrangement.

In the early stages of electric operation, there was a very large number of automatic circuit breaker openings for which there was no visible cause. Many of these were due to overhead or train equipment troubles which occurred periodically and the small amount of burning made it impossible to locate the fault by ordinary inspection. Others were known to be due to motor flashovers caused by wheels slipping on wet rails; this is now avoided by proper handling of the trains by motormen.

To trace recurring troubles, a systematic record of automatic circuit breaker openings is kept. For each automatic opening a notation is made in this record of the train in the trolley section, the numbers of the motor cars in the train, location of the train, and the name of the motorman. The following results were and are obtained from the study of periodic summaries of this information:

1. Motor flashovers due to slipping of wheels was confined to a few motormen. These motormen were given special instructions and motor flashovers from this cause have been reduced from about thirty per month to about three per month, and the damage is almost negligible.

2. If an unusual number of circuit breaker openings is found to occur at times when trains are passing a certain point, a thorough inspection of the overhead is made, which usually results in the discovery of a catenary defect at the location.

3. Car equipment trouble is shown by an excess of circuit breaker openings marked against a particular car and this car is taken in for inspection. These inspections invariably verify the evidence shown by the automatic opening report.

It is believed the tracing of these faults before serious damage results is made possible by the high speed characteristics of the circuit breakers.

Disadvantages

There is theoretically an inherent defect in the high-speed breaker characteristics as applied in this service with a short circuit occurring at the time of heavy traction load. When the circuit breaker is carrying heavy current in the right direction for its operation and a short circuit occurs on an adjacent section not directly fed by the breaker, there is a possibility of the breaker opening automatically and incorrectly from the selectivity standpoint. This incorrect operation is due to the load current superimposed on the short-circuit current, the effect being to lower the critical rate of current increase which will open the breaker on short circuit. Actually there have been very few incorrect automatic openings of circuit breakers which have been traced to this cause.

The setting of high-speed circuit breakers on the Illinois Central is accomplished by turning a one-inch iron screw in or out of the holding coil core, thus varying the reluctance of the holding coil magnetic circuit. A marked brass calibrating plate serves as a scale. Such a method of setting is not very accurate considering that highly selective operation is expected. Also, a circuit breaker truck must be removed from the circuit in order to change the setting.

The breaker setting is changed somewhat by the wearing of the main contacts, and periodic calibrating will probably be necessary. Such calibration would require artificial loading which would be cumbersome with 5000- or 6000-ampere settings. However, this will be an infrequent procedure.

Although its advisability may be questioned, it is a practise of most operating companies to relieve traffic congestions by holding carbon circuit breakers closed for a short time. The high-speed circuit breaker does not permit this practise and three cases of breakers opening on legitimate load on the Illinois Central have resulted in serious delays.

It is sometimes desirable to burn clear a minor short circuit. This is almost impossible due to the high-speed operation. In one case, a No. 12 A. W. G. meter lead grounded to the meter frame and could not be burned clear. This occurred on a test train previous to regular operation, but could have caused serious delays had it occurred in regular service, since it was difficult to locate.

The injurious effects of the high-voltage surges induced by the high-speed operation have sometimes been cited as a disadvantage of the device. These surges amount to approximately double the line voltage and are greater than the surges due to openings of carbon circuit breakers. There has been no direct evidence of damage caused by these surges on the Illinois Central.

A number of minor changes in design of the high-speed breakers has been effected since the original installation. These alterations were made by the manufacturers to correct faults which developed under operating conditions. As an example, considerable trouble was experienced by the breakers pumping, due apparently to bouncing of the armature against the core. This pumping often resulted in the reset coil burning out. A change in design of the reset coil core has corrected this defect.

The reset coils of the present high-speed breakers seem to be designed with only a narrow margin of safety as regards operating temperature, since they will reach dangerous temperatures if operated at too frequent intervals. A more liberal design of coil would correct this disadvantage.

Two serious substation bus short circuits were experienced, which may have been due to insufficient clearance of the sheet metal enclosure of the breaker mechanism. The circuit breakers are now being mounted on an ebony asbestos base, instead of metal, and no further trouble is expected. It is understood the manufacturer is incorporating this change of design in all new high-speed circuit breakers.

It was necessary to raise the overload setting and to remove all but 3/8 in. of the iron on the inductive shunt of the positive machine breaker in the substations, which was set for a low value of reverse current. A sudden interruption of current in the normal direction (such as opening of a feeder breaker) causes a reverse flow of current in the bucking bar due to the collapse of magnetic flux in the inductive shunt, the effect being to open the breaker unnecessarily. The changes in the setting and inductance of the shunt obviate this difficulty.

The foregoing paragraphs are a brief review of the advantages and disadvantages of the high-speed circuit breakers in railway service as experienced by the Illinois Central Railroad. It is the opinion of the writers that railway men are more interested in the disadvantages since the advantages are more easily ascertained. If emphasis has been placed in the disadvantages, it should not be construed to indicate dissatisfaction on the part of the Illinois Central. The advantages of this installation of high-speed circuit breakers undoubtedly outweigh the disadvantages.

IMPRESSIONS OF THE A. I. E. E. CONVENTION AT DENVER

Last week electrical engineers gathered in Denver for the convention of the American Institute of Electrical Engineers. They had a good meeting and added further proof of the value of the Institute as an agency for progress. At the meeting of the chairmen of Institute sections and branches delegates from forty states discussed frankly the duties and obligations of engineers to help build a better profession and a better country. These men deserve the support of the industry.

Notable principles were enunciated by President Gherardi and President-elect Schuchardt. In his presidential address Mr. Gherardi said that the engineer and his works contribute the power and machines which produce the capital and leisure that make possible the cultural, material and spiritual values in modern civilization. President-elect Schuchardt urged each member to use his special knowledge and talents for civic good as well as for engineering advance.

Committee reports recorded recent advances in detail and are most valuable as summaries of the art. The technical meetings were splendid. The power group discussed recent field data on surges from lightning. Not many conclusions could be drawn, but in a short time the answer to the lightning problem will be had. Another technical meeting, on high-speed breakers, showed that railroad electrification is proceeding apace through the development of new equipment. The list of technical papers was representative of all branches of the art and recorded new things or better ways of doing old things. The engineers are alert to their economic responsibilities and are striving to advance their art as fast as possible.

A gifted pen should be devoted to the electrical engineer. He needs to have the notable things he has done translated into human values in terms of romantic achievement and adventure in pioneer territory. One of the handicaps of the engineer and of the industry is that technical specialization is far in advance of the ability of the public to understand these engineering advances. It is sometimes said that the engineer does not understand the value of human relations, but it is equally true that most people do not understand the engineer or his works. Electric welding is needed to bind the electrical engineer to his industry and the public.

The Denver meeting again bore witness that the Institute is a vital and vigorous tool for industry progress. The electrical engineer, in a quiet and effective way, continues to provide the power and the machines that make for growth and advancement.—*Electrical World.*

Corrosion of Cable Sheath in Creosoted Wood Conduit

BY R. M. BURNS[1] and B. A. FREED[2]

Non-member Non-member

FOLLOWING the successful use of conduit of creosoted yellow pine in the eastern and southern part of this country, similar duct made of Douglas fir was introduced on the Pacific Coast in 1911. Manufacture was undertaken in the Puget Sound territory; and extensive use of the duct has since been made for both main and subsidiary communication subways in all parts of Washington, Oregon and California, excepting Southern California where its field has been limited by economical considerations to lateral or subsidiary construction. This conduit was also considered satisfactory, until the latter part of 1923, when corrosion developed on some newly placed telephone cables, and the attending circumstances were such as to indicate that the duct itself might be responsible. It is with the identification of this corrosion and the determination and application of methods of allaying it that this paper is concerned.

Discovery of corrosion presented a problem of some magnitude in so far as the application of palliative measures was concerned. Between 1911, when wood conduit was first introduced on the Pacific Coast, and 1926, when its manufacture for the Bell System was discontinued because of its effect upon the sheath of the cables, approximately 7,250,000 duct ft. were placed as telephone subway; and cables had been pulled into about one-third of it. This problem was simplified to some extent, however, by the fact that the cables had not been affected in all duct runs. There were also approximately 130,000 duct ft. of conduit in the store yards, the salvage of which was, of course, very desirable.

The conduit is made of 4½ in. by 4½ in. sections of timber having a three in. bore, and mortise and tennon ends. The practise has been to machine it while green, as a rule within five days after the felling of the timber, to overcome the losses which would otherwise occur due to splitting of the duct during the boring process. Until about 1915 the conduit machinery and treating plant were at the same location. Since this date, however, it has been necessary to transport the conduit by barge, from the mill at which it is machined, across Puget Sound to the treating plant. This and other movements of the conduit, which occur between machining and the time it enters the retorts of the treating plant, are made as expeditiously as possible to obviate the checking in thin sections of timber during air seasoning. To avoid this every effort has been made to place the conduit in the retorts within four or five days after it has been machined. Thus, the entire process of manufacture including the felling of the timber and its treatment rarely has exceeded ten days.

Within the period that conduit of this material has been in use, two types of treatment have been employed. The purpose of both of these treatments was to obtain an absorption of 15 lb. of creosote oil per cubic foot of timber by what is known as the "full cell" process, as contrasted with the "empty cell" process, but the movements followed in the application of pressure, heat, and oil have been somewhat different. The creosote oil used with both types of treatment was an imported grade of dead oil of coal tar, or coal tar creosote, and was obtained from the same sources. It has consisted wholly of distillates of gas tar produced by the destructive distillation of bituminous coal, either in the manufacture of coal gas, or in manufacture of coke by the by-product process. So far as is known, the only variation in composition shown by the creosote during the period was in the tar acid content. This has fluctuated to some extent but has never exceeded 10 per cent.

The original process seasoned the wood by boiling it in creosote oil. This operation was followed by application of sufficient temperature and pressure to permit the forcing of the required amount of oil into the duct. In 1916 this method of treatment was superseded by the "vacuum" process which had been developed a short time previously, primarily for use on bridge stringers, etc., the effect upon the fibre strength being decidedly less detrimental. The principal advantages of the new process, as applied to conduit, were that it minimized the losses in treatment from checking and distortion, and presumably resulted in obtaining a better spread of the preservative. Of the latter point however, there is considerable doubt. With the vacuum process, the wood is immersed in creosote oil an subjected to a minimum vacuum of 20 in. of mercury and to temperatures ranging between 190 deg. fahr. and 200 deg. fahr. until the moisture content is reduced to approximately the fibre saturation point, after which pressure is applied until the timber has absorbed the required amount of oil. At the end of the pressure period the retorts are emptied of preservative, and a vacuum of 20 in. of mercury created for about two hours, under an average temperature of 160 deg. fahr. The entire treating process consumes about 20 hr. on an

1. Bell Telephone Laboratories, Inc., New York, N. Y.

2. Pacific Telephone & Telegraph Co., Seattle, Wash.

Presented at Pacific Coast Convention of the A. I. E. E., Spokane, Wash., Aug. 28-31, 1928.

average, and is of somewhat longer duration than the earlier process.

In the light of more recent experience it has become apparent that cable failures due to corrosion by creosoted wood conduits occurred prior to 1923, but were at the time attributed to other causes. The first case which can be ascribed with any assurance to creosoted wood occurred at Yakima, Washington in 1921. Even as late as 1925, however, it was not certain that the trouble was associated with the conduit. The fact that creosoted wood had not been known previously to cause corrosion, that there had been no change in the wood or creosote used in the manufacture of conduit, that other users of creosoted wood conduit had not reported trouble, all tended to absolve the conduit. The change in the method of creosoting introduced in 1916 was not such as to arouse suspicion, and moreover so far as was known, corrosion did not follow immediately after the change in process. When late in 1923 serious cases of corrosion occurred first in Seattle and then in San Francisco and elsewhere on the Coast it became evident that the action was not due to the soil as was suspected at first. A study of soil samples from the points of failure also had given no indication of unusual acidity. It was recognized that the trouble could not be due to electrolysis since its occurrence bore no relationship to the potential condition of the cable with respect to earth and since perforation of the sheath occurred on the top or sides of the cable which were not in contact with the duct, and then only in duct runs which were free from water and well drained. Corrosion was never experienced on cables which were submerged in water continually or for a part of the year. On the other hand, the action was facilitated by the condensation of moisture in the form of droplets on the cable. That climatic conditions, particularly temperature and humidity, were important is seen in the fact that in the region of Seattle, corrosion was rapid only in the Spring and Fall, whereas in San Francisco it occurred at much the same rate the year around. The alloy used for cable sheath in recent years consisted of 99 per cent lead and 1 per cent antimony, and the question arose as to whether the sheath suffering corrosion was of normal composition. Chemical and microscopic analysis, however, showed it to be of the composition specified and not abnormally susceptible to corrosion.

Corrosion of the type experienced manifests itself by the formation of a white encasement around the globules of moisture condensed on the sheath. In the early stages a mottled effect is produced, but as the attack progresses, the surface of the cable, particularly the top and sides, becomes heavily coated with a white encrustation of lead carbonate or basic carbonate, as is shown in Fig. 1. Chemical analysis of this product gave an indication also of the presence of volatile organic acids. Beneath the carbonate coating the sheath was pitted corresponding to the original globules of moisture. It was perforation of the sheath by these pits which led to failure of the cables. In one instance an 18 in. section of sheath displayed seven perforations.

The persistence of corrosive conditions with time has been a matter of great interest. Observations have indicated that the corrosive qualities of the conduit become depreciated with time and are influenced to some extent by conditions of ventilation, its exposure to the weather before installation in the ground, etc. A recent analysis of the corrosion failures in one locality has shown that about 70 per cent of the failures occurred on cables which had been under ground for less than 15 months, and furthermore, that about 90 per cent of the failures occurred in conduit which at the time the cables were placed in it had been in the ground for less than 13 months. In mitigation of these facts it should be pointed out that possibly sufficient time had not elapsed for many cases of the less active corrosion to reveal themselves and further, that in most cases the conduit was laid for immediate occupancy and service conditions

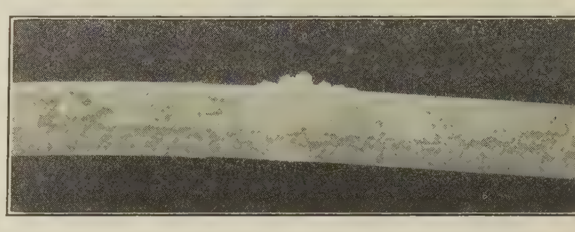

Fig. 1—White Carbonate Formed on Lead Cable Sheath

have not been such as to warrant the later installation of cables, the performance of which would indicate the persistence of corrosive conditions.

The volatile nature of the corroding agent was evident from the fact that the corrosive action in many cases extended into the manhole beyond the mouth of the ducts. This was particularly noticeable in manholes situated on hillsides where the action was visible on cables leading into the manhole from the lower side, but was not discernible at the mouth of the ducts on the side leading up-hill.

A careful consideration of the facts disclosed by field observations led to the conclusion that the most likely cause of corrosion was to be sought in the high proportion of carbon dioxide and other acid vapors in combination with humidity changes in the duct atmosphere. It had been shown previously that the characteristic attack could be imitated in the laboratory by exposing pieces of cable sheath bearing drops of water to moist air containing carbon dioxide and a trace of acetic acid vapor. A more quantitative method of determining the rate of corrosion so produced was developed later and consisted in the measurement of the rate of increase in electrical resistance of extruded lead wires which resulted when these wires were reduced in cross-section by the progress of corrosion. This

method was particularly useful later in testing the effectiveness of various palliative treatments.[3]

Having concluded that the corrosion was definitely associated with vapors present in the duct it became desirable to investigate the composition of duct air where corrosion was actually in progress and for this purpose a portable apparatus was developed. It consisted essentially in an aspirator, a trap for freezing out volatile vapors, a thermal conductivity cell with a Wheatstone bridge arrangement for measuring carbon dioxide and wet and dry bulb thermometers for determining the humidity. The aspirating device was a small mechanical pump and was driven by a motor which was operated on a six-volt storage battery. Capillary flow meters were used to measure the flow of air from the duct. The most suitable rate of air-flow was found to be from 9 to 11 cu. in. per min. The temperature of the vapor trap was maintained near –110 deg. fahr. by surrounding it with solid carbon dioxide. An auxiliary set of vapor traps made it possible to study the air from four ducts simultaneously. The apparatus was mounted generally on a truck, which during a test, was parked beside a manhole. Glass tubes led from the apparatus to the ducts. The conductivity cell was calibrated for the range 0.1 to 20.0 per cent carbon dioxide and the values could be read to 0.05 per cent. The substances obtained in the vapor trap were analyzed in the laboratory for tar acids and acids of the acetic type and tests were made for aldehydes, sulphur compounds, nitrates and chlorides.

After preliminary work with this apparatus in New Jersey had shown it to be suitable for the purpose, it was taken to the Pacific Coast and used at Seattle, Tacoma, Portland, San Francisco, Oakland and Los Angeles. In the 25 runs which were made there were included both corrosive and non-corrosive creosoted wood ducts, tile ducts, and fibre ducts. Some of the ducts contained cables and others had never been occupied. In one case the apparatus was set up in a central office cable vault and operated continuously for three days on a bank of corrosive ducts which led into that office. Most of the wood conduit studied had been placed since 1920 but in two cases it dated from 1914. Finally runs were made at the creosoting plant which had manufactured the conduit, vapors being collected from the air in the work-storage and condensate tanks.

The results of these tests showed that small amounts of a volatile organic acid, probably largely acetic acid, were present in the air in creosoted wood ducts which had been installed in recent years, and that in general, the higher concentrations of acid were found in the more corrosive sections. Although the actual concentration of acid calculated as acetic acid did not exceed 0.1 mg. per cu. ft. of air, previous laboratory investigations had shown that acid concentrations of this magnitude were definitely corrosive to cable sheath. The runs made at the creosoting plant revealed the presence of still greater concentrations of acid in storage tank air, the values being from two to four times greater than those found in conduit air.

Tar acids and naphthalene were collected in considerable quantities from the creosoted wood ducts, but neither of these substances, nor carbon dioxide, within the limits found, 0.1 per cent to 6.0 per cent, bore any relationship to the corrosive action. Nor did these substances show in laboratory tests, the marked corrosive action displayed by traces of acetic acid.

In the meantime, additional laboratory tests had shown that green Douglas fir wood contains considerably larger quantities of volatile acid than does southern pine or western hemlock and that the corrosive qualities of sawdust samples of these woods are related to their acid contents.

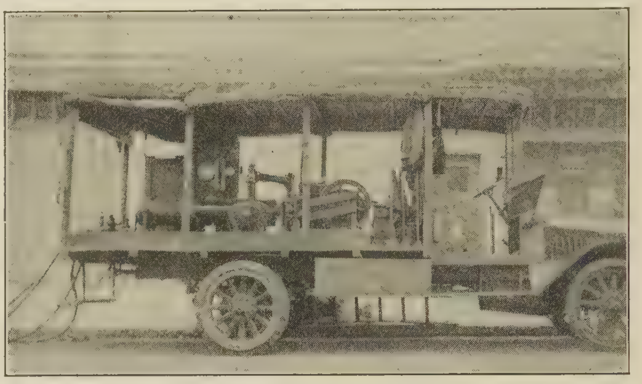

Fig. 2—Apparatus For Supplying Ammonia to Neutralize Creosoted Wood Duct

It had become evident in view of these observations that corrosion was due to acids derived from the conduit and therefore from a knowledge of wood chemistry principally acetic acid. Hence, the mechanism of the corrosion is the same as that involved in the production of "white lead." This reaction, from the classical viewpoint, consists in the formation of lead acetate, by the action of acetic acid and oxygen on lead, and the conversion of this product into a basic lead carbonate with the liberation of acetic acid which then repeats the process cyclically. Essentially the process is dependent upon the maintenance of a suitably high concentration of hydrogen ions and the presence of oxygen and carbon dioxide.

The determination of the cause of corrosion was in one sense only preliminary to the important problem of finding a means of saving the cables which were in the process of corroding and to devise a method of treatment which would destroy the corrosiveness of idle ducts prior to their occupancy by cables. In this study comprehensive tests were carried on both in the field and in the laboratory. A large number of materials, including

3. The development of this method of measuring corrosion rates was due to W. A. Hyde and W. E. Campbell of the Bell Telephone Laboratories and will be described in more detail in a later paper.

petrolatum, greases, oils, soap solution, water glass, pyridine, ammonium carbonate, ammonium dichromate, ammonia gas, etc., were tried out. Heavy petrolatum applied to cables upon installation gave some promise, but examination of the coated cables later revealed marked evidences of corrosion in areas where the grease had been rubbed off during the installation of the cable. Eventually the most effective palliative treatment was found to be ammonia gas which neutralizes the acetic acid forming ammonium acetate, a non-volatile salt.

A suitable apparatus was developed for supplying ammonia mixed with air to cable ducts. This equipment consisted of a large capacity blower operated by a gasoline engine, a mixing tank, the necessary connections and an outlet through a manifold for distributing the air mixture to the ducts. A tank of liquid ammonia was connected to the mixing tank through a flow meter. The system was mounted on a truck, as is shown in Fig. 2. The air-ammonia mixture found most suitable contained about 2 per cent ammonia, and this was used. The greater part of the affected creosoted wood conduit in the plant has now been given the ammonia treatment with the result that trouble due to corrosion has practically ceased. There is still some question as to the necessity of repeating the treatment, but the evidence indicates that a single application will suffice in perhaps all but the most severely corrosive ducts.

The final phase of the problem, not yet completed, has had to do with the determination of the source and process of formation of the corrosive acid in creosoted wood ducts. An extensive laboratory investigation has shown that Douglas fir is markedly more acidic than pine, which is used for conduit in other sections of the country, and that the acid content is increased by raising the temperature or increasing the duration of heat treatment. Douglas fir is particularly difficult to penetrate with creosote and the relatively longer duration of treatment which has been employed in an attempt to improve penetration has tended probably to increase the acid content of the product. There is evidence that the acid is associated with the untreated part of the duct and that the creosoted portion of the wood is not corrosive to cable sheath.

Civilization and the Engineer

President's Address

BY BANCROFT GHERARDI

What has the engineer contributed to civilization? Have his contributions been major factors in its development? It is important that we should know the answers to these questions, for sooner or later the standing of the engineer in the world in which we live depends upon these answers. To get them it is necessary to consider the development of civilization.

From the earliest days, mankind's primary need has been food. He cannot exist without it. In addition, in most climates he must have shelter, clothes and fuel. As long as all human energy had to be devoted to meeting these needs, no margin remained for the improvement of man's condition, either physical, mental, or spiritual. It is to the extent that there is a margin of effort available after the minimum of these requirements is provided that civilization may develop. The existence and magnitude of such a margin has depended upon man's willingness and ability to produce beyond this minimum and the aids that he has in his work. The margin beyond that necessary for maintaining existence goes to the improvement of his status.

The students of the early stages of man's development measure the steps by which he has advanced by certain outstanding factors. Accepting the classification of Lewis H. Morgan, these are: The development of speech; the use of fire; the bow and arrow; the manufacture of pottery; the domestication of animals; the development of writing. In these, we find the beginning of civilization. And we find something more; something of the deepest significance to the engineer. Fire,—first used for warmth and cooking, and now our principal source of power. The bow and arrow—a machine by means of which man can apply his strength and dexterity more effectively. Pottery,—a manufactured article to minister to his household needs. Domestic animals,—a source of power under the control of man and a more reliable supply of food and clothing. Although at that time scientific knowledge was unknown, invention probably not recognized as such, and engineering not even dreamt of, in the bow and arrow and in pottery all were foreshadowed.

The struggle by man to learn the facts of nature and to utilize them has been slow and extended over ages. As we look back, at times progress has seemed to halt, and generally, there was no definite conception of what constituted progress or in what ways it should be sought, but nevertheless, the ground work was being laid and man was slowly moving forward.

There gradually grew up an appreciation that Nature was not whimsical or beyond understanding; that she has hidden treasures—materials and forces—that could be used by man if he would but learn

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what they were; that Nature was an inexhaustible treasurehouse if man would but find the "open sesame," the way to use her resources—and that the "open sesame" was to learn of Nature by studying her and not by trying to speculate what she should be; that we may theorize if our theories are based on facts and checked by experience, but that speculations without facts are idle dreams and that nothing that may be determined by observation may be safely accepted except as it is so determined. Early there were such minds,—Euclid, Archimedes, Aristarchus, Hipparchus,—but in their time they did not represent the common method of thought even of the educated people.

Then came a long period of halting, "the dark ages," during which not only did progress seem to cease, but in many cases it was discouraged by powerful authorities. But the greatest darkness always comes just before the dawn.

In the 16th and 17th centuries, the scene began to change rapidly. A number of wonderful men of whom I shall name only two,—Galileo and Newton,—devoted their lives to the study of nature; that is, to the getting of facts and to the effort to develop theories that would be consistent with these facts; and which could be used to postulate other facts which, if verified by observation, further extend knowledge. These men were the pioneers in our modern civilization. To these and to their successors in theory and application we owe the developments that constitute the determining factors of modern civilization.

And what are the characteristic features of the material aspects of modern civilization? They are power and machines.

Power by which man power and horsepower are multiplied to practically any extent that may be desired, and machines which, when driven by power, will make or do numberless things which man may desire. At last it is possible for man, aided by power and machinery, to produce so far beyond the primary needs of food, shelter, clothes and fuel, that not only can he greatly improve the quantity and quality of these, but provide numberless other conveniences, comforts, and luxuries; and these results are attained today with shorter working hours than formerly were necessary to achieve a much lower standard of living.

These results have been a direct outcome of the work of the scientist, the inventor, and the engineer. And to these should be added other groups engaged in the practical application of science,—such as chemists, biologists, doctors, and architects. They have been contributed to also by the promoter, the manager, the banker and the capitalist—all necessary factors in the development of modern civilization but without the products of science, invention, and engineering, they could not have builded as they have. For not only is our modern civilization based upon science and its applications but these have furnished the capital necessary to realize the results attained. For capital is the margin between what we produce and what we consume for our day-by-day needs, and this margin is mostly due to the applications of science. Suppose that today China should decide that it should have transportation and a communication system equivalent in proportion to its population to that of the United States. How would it go about getting such a system promptly? There is no way that it could do so. In material and labor, this system would cost say 200 billion dollars, for highways, railroads, motor cars and telephone plants. This could not be borrowed, because aside from any question of credit, there is no such surplus available in the rest of the world; it is not to be had, because so much has not been saved in its whole existence of several thousand years.

This brief outline of the development in the material aspects of modern civilization indicates sufficiently the part that has been taken in it by the scientist, the inventor and the engineer. I have confined myself largely to the material aspects because the very nature of engineering has to do with physical things. Should it be inferred that the engineer has made no contribution to the mental and spirtual advance of mankind? The facts by no means justify such a conclusion.

Consider the printing press and its relations to the diffusion of knowledge. The phonograph and what it has done for music. The moving picture, and now the talking movie and their part in education and entertainment. Radio broadcasting and its bringing millions in direct touch with the finest orchestras, the greatest educators and entertainers, and enabling millions to hear the President of the United States when he speaks on a public occasion. The farm telephone and the automobile and what they have done to break down the isolation of farm life. Is the world's great transportation system—railroads, motor cars, and steamships—used solely for business? Has travel ceased to have an educational value since the slowness, expense and discomforts of the stage coach and of the sailing ship have been eliminated from it? And our communication system—mail, telephone and telegraph—does it contribute nothing to our higher life? Is it never used except in relation to the material aspects of life?

If such contributions to our mental and spiritual development were all that have been given to the world by the engineer and his allies, they would be notable and more than refute the statement sometimes made that the engineer's contributions are solely materialistic. But this is by no means all.

The development of culture requires leisure from the struggle for existence. Was Athens the poorest nation in the world when it developed its wonderful literature and arts? It was materially the richest of its time. Was Florence, when it developed its school of painting, a poor and struggling city? Quite the reverse. Do we look today to Patagonia or Tasmania or to the Esquimos for high mental and spiritual development? We should if material welfare was inconsistent with spiritual and

mental attainments. History justifies the statement that material, mental, and spiritual development as a whole go together, and that while a genius may develop under almost any conditions, a high and distributed culture is favored by a high and distributed material welfare. The scientist and engineer have sometimes done themselves injustice in assenting to statements and occasionally even suggesting, themselves, that they have not contributed except to the material welfare of the world.

Still another outgrowth of the development of science and of its application is the educational system of today. Not always is it realized that for the maintenance of our present educational system in this country, it is a necessity that there should be a sufficiently high standard of living to permit of the withdrawal from the immediate production of the necessities of life the hundreds of thousands of teachers who are directing this educational work and the millions of students who are taking part in it. It is also necessary that there should be available huge amounts of capital to be expended for the provision of buildings and other necessary equipment. All of these have been rendered possible only by the results of applied science in increasing the margin over and above that necessary for existence.

From the beginning of history, man has constantly struggled to improve his economic status. He has wanted an assured supply of food and more pleasing food, more comfortable and better lodging, more comfortable, better and a greater variety of clothes, better shelter, more comforts of all kinds, more leisure and recreation, and now, through the tapping of the resources of nature, year by year and decade by decade, he is attaining these ends more and more, not only for the favored few but for the great mass of the people who, but a few decades ago, were believed to be condemned by the very nature of life in this world to an existence limited to the barest necessities. This sweeping change in the economic status of individuals and nations has given rise to many questions of a fundamental character. These questions have to do with social relations, education, economics, business, health, politics and religion. They comprehend the whole relationship of man to man and of man to his environment.

These questions do not depend for their solution upon engineering principles which so largely rest upon the characteristics of physical and inanimate things, but they have to do rather with people and with human reactions. This, however, does not take them out of the field in which the engineer must be skilled to do his work. For even though the engineer's main duty lies in the control of nature, the very organization of society which that control has given us means that the engineer, in his engineering work, must operate as a part of organized society and conduct his relations with others with due regard to human reactions. The conquest of nature on a large scale must be done by those who can use organizations of men. The modern engineer should have as great a capacity for human management, cooperation and for dealing with others as the men in politics, religion and other professions which are devoted primarily to the study of man. To the extent that the engineer can measure up to these requirements he may become a leader in other fields of action, as well as being a leader in his own.

Whatever may be the part of the engineer in the solution of these questions, his principal work and that which he only can do well, is to take the scientific facts made available by the scientist and, by their adaptation to practical ends, add to the welfare of mankind. And can we engineers, notwithstanding the stupendous advances of the 19th century and the gigantic steps forward of the first quarter of this century, doubt that still greater opportunities lie before us year by year, as with pride in the service that we render mankind and humility that so little has been done and so much remains to be done, we continue our work devoted to making this world a better and easier one to live in so that the burden of life may be lifted more and more from the shoulders of the average man.

ELECTRICAL HARDENING AND ANNEALING

Electric salt bath furnaces have been found to be very useful for heating metals up to the exact temperature required for hardening in the shortest possible time. They are largely employed for hardening cutting tools. The tool to be hardened is placed in the salt which is to carry the electric current. When the salt melts it makes good thermal contact with the metal, the required temperature being attained very quickly. The salt bath also serves as a heat accumulator. Air is not in contact with the heated metal, and so it is not oxidized on quenching. Owing to the excellent way they retain their heat, salt bath furnaces are particularly suitable for hardening metals on a large scale. In *Progress* for December, a description is given of electrical welding and hardening processes. The furnaces for 800 deg. cent. are used for hardening carbon steels, and those for 1300 deg. cent. for high alloy steels. The salt used for temperatures from 750 deg. cent to 1000 deg. cent is composed of a mixture of barium and potassium chlorides, and that from 1000 deg. cent. to 1300 deg. cent. of barium chloride only. Electric annealing furnaces are also described. For these furnaces chrome nickel has been found most useful for the conductor which converts the electrical energy into heat. These furnaces are generally designed for temperatures up to 950 deg. cent., and are specially useful for heating processes which have to extend over long periods. They are sometimes equipped with automatic temperature regulators, and can be used for annealing metals in hydrogen and other gases. The tempering of hardened tools can also be effected in electric salt bath furnaces even when the temperature required is so low as 220 deg. cent. In this case the conducting salt is a mixture of sodium and potassium nitrates.—*World Power.*

Abridgment of

Calculation of Stray Load Losses

BY G. H. ROCKWOOD[1]

Student Member, A. I. E. E.

Introduction

EARLY in the history of the development of the a-c. generator, it was recognized that there were losses present under load conditions in addition to the no-load losses and the armature copper loss due to load current. Because no one had a satisfactory means of measuring this loss it was not included in the early definitions of conventional efficiency. As competition increased and economic pressure demanded higher and higher efficiencies, the necessity of approximating this loss was apparent.

At the Midwinter Convention of the A. I. E. E. in 1913 papers were presented giving the results of carefully made input-output tests which tended to show that the entire loss on sustained polyphase short circuit should be taken as a measure of the stray-load loss for the salient pole alternator. This rule has remained in force and in view of its general acceptance, it is to the interest of designers of salient pole alternators to be able to predetermine this loss.

It is the purpose of this paper to present some general methods of attacking the problem. It is not intended that the results should be complete—they are presented simply as a starting point for the attack on this problem.

Proceeding on the principle that a formula cannot be correct unless it has the dimensions of the quantity which it represents or expresses, we may quite readily develop some of our familiar relations. As the complexity of the problems which we treat by this method increases, the difficulties encountered in its application also increase until a point is reached beyond which we cannot go without assistance.

In the case at hand,—the calculation of stray-load losses,—this assistance may come in one of two forms; it may be experimental evidence as to the exponents of certain of the variables, or it may come in the form of assumptions as to the variables involved and the manner of their variation. It is evident, therefore, that the method is not rigorous but is one which will enable us to derive a formula from otherwise incomplete data.

Formulas derived in this manner require the inclusion of empirical constants. These constants may be determined by statistical methods to be discussed later.

Instead of trying to develop a single formula for the short-circuit core loss, it is desirable to separate the total loss into distinct parts and develop formulas for each of these parts separately. The total loss is then the sum of the component losses.

The parts into which this loss is most conveniently divided are:

1. An eddy-current loss in the armature copper.
2. A loss in the stator iron.
3. A pole face loss.
4. An end loss.
5. A loss in the amortisseur winding.

Eddy-Current Losses in the Armature Copper

There is an extensive literature on the subject of eddy-current losses in the armature copper and there will not be space here to review it. In the investigation on which this paper is based the method used by I. H. Summers[2] was employed and assumed without error.

Loss in the Stator Iron

The flux wave form in the air-gap of a salient-pole alternator under load varies with the power factor at which the machine is operating. This condition renders it extremely difficult to determine the core losses under load. We are seeking, however, to express the core losses at a fixed power factor, and that with which we are concerned is one which gives rise to very special relations between the main field flux and the armature reaction flux. The power factor which we are to consider is extremely close to zero, in a lagging direction.

Since the flux densities under short-circuit conditions are not ordinarily found in the usual course of design, it will be necessary to determine them before the loss can be computed. It will be convenient to express them as a percentage of the open circuit densities.

If a salient-pole alternator operates at zero power factor, the axes of the main field flux and the armature reaction flux will coincide. If the power factor is leading, the flux waves will add; if the power factor is lagging, the net flux will be the difference of the two waves. The wave form of the two fluxes will not be the same, however, so the addition and subtraction mentioned above must be that of harmonics of the same order.

If we are to be able to calculate the flux wave existing in the air-gap of a salient-pole alternator operated on short circuit at such an excitation that rated current flows in the armature windings we must make certain assumptions. These assumptions are four in number and are given below:

1. Massachusetts Inst. of Tech., Cambridge, Mass.

National and District Prize Paper, presented at the Regional Meeting of District No. 1., at Pittsfield, Mass., May 25-28, 1927.

2. *Reduction of Armature Copper Losses,* TRANSACTIONS A. I. E. E., Vol. 46, 1927, p. 101.

1. That the air-gap flux wave consists of four components and four only.

   a. A fundamental due to the main field m. m. f.

   b. A third harmonic due to the main field m. m. f.

   c. A fundamental due to the armature reaction m. m. f.

   d. A third harmonic due to the armature reaction m. m. f.

2. That the four components of the flux wave are determined by the value of the three ratios:

   a. Maximum gap to minimum gap.

   b. Pole arc to pole pitch.

   c. Minimum gap to pole pitch.

3. That the armature reaction m. m. f. has a sinusoidal space distribution.

4. That the machine operates at zero power factor lagging.

There is a paper by Mr. R. W. Wieseman[3] giving curves for the determination of the four components of the short-circuit flux wave mentioned above in terms of the three ratios of assumption number two. The accuracy of these curves is discussed in the paper and no more need be said about them here. It will be assumed that these curves give the actual amplitudes of the flux wave components.

Before any addition of components can be made, we must find some common basis for their measurement, since the curves of Mr. Wieseman's paper give the four components as a per cent of the total wave of either armature reaction or main field flux, as the case may be. This common basis is found by expressing the m. m. f. applied under short-circuit conditions as a percentage of the m. m. f. required for the air-gap. This assumes that an ampere-turn on the field is just as effective in producing flux as an ampere-turn on the armature.

We must determine another constant, however, because the value of the armature reaction as determined by the usual design formula, for three-phase 2.12 $N\,I\,K_p\,K_d$ is based on a time distribution instead of a space distribution. This constant is $4/\pi = 1.27$.

Making use of this, the expression for the short-circuit air-gap density in terms of the open-circuit air-gap density becomes (for each component):

$$B_1 = B_{nL}\left[A_{1m}\left(X + \frac{A\,R}{F_g} \right.\right. \left(+ \frac{1.27\,A\,R\,A_{1a}}{F_g} \right]$$

$$B_3 = B_{nL}\left[A_{3m}\left(X + \frac{A\,R}{F_g} \right.\right. \left(+ \frac{1.27\,A\,R\,A_{3a}}{F_g} \right]$$

The density distribution which has just been described will not obtain in the iron portions of the machine. It may be shown, however, that the only component which we need consider is the third harmonic in the teeth. This will be expressed by an equation similar to (1), except that B_{nL} will be replaced by the no-load tooth density. The loss will then be:

$$W_t = K_1\,K_i\,K_f\,\frac{\text{volume of teeth}}{1000}\,w_3$$

To calculate the triple-frequency core loss in the armature teeth for the condition of sustained polyphase short circuit it is, therefore, necessary to compute the third harmonic tooth density as a percentage of the open-circuit tooth density and then to obtain the loss from the usual laboratory loss curves.

Short-Circuit Pole-Face Loss

Under sustained polyphase short circuit the current carried by each slot will give rise to an m. m. f. which will cause flux pulsations in the pole face. The magnitude of the loss produced will be a function of these tooth-frequency flux pulsations. Since the path of this flux is largely in air, we may assume as a first approximation that it is directly proportional to the m. m. f. producing it. This m. m. f. will be proportional to the current per slot, which, for any given machine, is in turn proportional to the ampere-turns per inch of armature periphery.

To derive a formula for the short-circuit pole-face loss, use has been made of a similar study of open-circuit pole-face losses. The method used was that of a dimensional analysis, starting with experimental values for the exponents of certain of the variables.

The final form of the short-circuit pole-face loss formula is:

$$W_p = K_2\,(16\,t)\left(\frac{H \times \tau_0}{100}\right)^2 \frac{P\,A}{1000}\left(\frac{V}{10\,g}\right)^{1.5}$$

End Loss

Under sustained polyphase short-circuit conditions the windings carrying current are linking the end fingers, clamping flanges and armature binding bands, thus inducing eddy currents in all of these portions of the machine. In addition there will be a considerable leakage flux from the end connections, some of which may get into the frame, end shields and various other stationary portions. It is understood, of course, that this flux of the armature winding which is producing end loss is revolving at synchronous speed, in consequence of the polyphase nature of the winding which produces a revolving field.

If we are to be able to compute the loss, we must first find the leakage flux producing this loss. This may be done by multiplying the m. m. f. by the permeance of the leakage flux path. The m. m. f., of course, will be the ampere-turns of armature reaction, or some fraction thereof.

It now remains to find an expression for the permeance of the leakage flux path. If we assume that the adjacent masses of iron may be neglected, we see that the permeance is of the form:

3. *Graphical Determination of Magnetic Fields*, by Robert W. Wieseman, Winter Conv., 1927; A. I. E. E. Trans., Vol. 46, p. 141.

$$C = \mu \times \text{pole pitch} \times \text{coil pitch}$$

Making the assumption of constant permeability and using a formula derived by dimensional analysis, the end loss formula becomes:

$$W_e = K_3 \frac{D\,V\,\sqrt{f}}{1000}\left(\frac{A\,R}{10{,}000}\right)^2 \times \text{coil pitch}$$

Loss in the Amortisseur Windings

Thus far we have assumed that the armature reaction m. m. f. was sinusoidally distributed about the periphery. With a finite number of phases this can never be exactly true, but for the losses thus far considered the approximation has been close. There is, however, a loss due to the fact that the armature reaction m. m. f. is not sinusoidal. The wave form of the armature reaction m. m. f. will be determined by the pitch of the winding and by its arrangement in the slots. For our present purpose the effect of pitch alone will be considered. In many cases the arrangement of the winding will be more important, but here it is our purpose to produce a formula which shall be comparatively simple to apply in a specific case rather than to obtain one which gives greater accuracy at the cost of increased labor.

If the pitch is such that the wave form is not sinusoidal there will be certain of the higher harmonics which will move relatively to the pole faces. The triple harmonics will cancel in the three-phase machine leaving all others to produce loss. Of these, the fifth and seventh are the most important.

If we recognize the fact that, so far as this loss is concerned, the synchronous machine may be treated by an equivalent circuit exactly similar to that for the single-phase induction motor, we may arrive at the desired approximation. By the use of this circuit we may deduce an expression for the loss in the bar windings of the rotor as some function of the stator coil pitch. To determine the form which this function will take, we must remember that the flux harmonics due to the arrangement of the winding will also produce a leakage reactance drop in the phase belt. This reactance is easily calculable for the induction motor and we may simply use values taken from such a curve for the values of this function of the coil pitch. This apparent mixing of the units of loss and reactance is not real, since the units are proportional, and we shall prefix this expression for the loss by a constant to be determined by statistical methods.

A dimensional check of the formula showed that it was dimensionally correct. In its final form, it is:

$$\text{Loss in bars} = K_4\left(\frac{A\,R \times P}{100{,}000}\right)^2 \frac{L}{D} \times Q \times K_\rho$$

Determination of the Values of the Proportionality Constants

Each of the terms in the formula for short-circuit core loss has been prefixed by a coefficient. These coefficients have been included because the formulas as developed are not rigorous and they must be determined from considerations derived from the theory of probability. In determining their values, we seek to find the most probable value for each one of the four coefficients. Statistical theory indicates that the most probable value of any observed quantity is that which makes the sum of the squares of the deviations of a set of observations, or a group of such sets, a minimum. In accordance with this theory, the method of least squares may be applied for the determination of the values of the coefficients.

Accuracy of the Formula

In using any formula such as this, the designer of electrical machinery is interested not only in the error inherent in the formula but the probable error of the result. If the results of using this formula be plotted as a frequency distribution, *i. e.*, per cent error in each individual case against the number of times it occurs, the usual normal distribution or probability curve will result. The fact that we have such a distribution is the thing of greatest interest to the designer. Associated with such a distribution are a number of means intended to give a reliable index of the accuracy of the result. One of the most convenient of these is the mean deviation.

The usual manner of measuring the accuracy of such a formula is to form the ratio

$$\frac{\text{Test core loss}}{\text{Calculated core loss}}$$

for each application and to determine the mean deviation of this ratio. When dealing with stray-load losses as determined by the sustained polyphase short-circuit test, however, it is more convenient to express the error as a percentage of the copper loss at full load current. This is done for several reasons; first, it has been experimentally shown that the stray-load loss, or short-circuit loss, varies with the square of the current as does the copper loss, and so it is natural to treat it in the same manner. Secondly, it has been the practise of designers from time immemorial to estimate this loss by assuming it to be a percentage of the copper loss at rated current. We shall, therefore, be measuring the accuracy of the formula in a unit which is already understood by those who are to use the formula. Finally, it is desirable to minimize the testing errors which are greatest where the loss is but a small part of the copper loss.

Measuring the accuracy of the formula for its application to 150 machines, the results are as follows:

Mean deviation	27.5 per cent
Average error	10.9 per cent
Maximum error	
Plus	41.2 per cent
Minus	41.5 per cent.

The above errors are expressed as a per cent of the full load copper loss.

In conclusion it must be pointed out that the accuracy of the experimental determination of this loss, thus far assumed to be without error, is not all that could be desired. In measuring the short-circuit loss per the A. I. E. E. rules it is necessary to deduct from the measured input not only the friction and windage but the armature copper loss as well. Thus, the loss we are seeking to determine is not capable of direct measurement but is a measured loss minus other more or less accurately determinable losses.

TABLE OF SYMBOLS

A_{1m} Amplitude of fundamental of main field flux wave
A_{3m} Amplitude of third harmonic of main field flux wave
A_{1a} Amplitude of fundamental of armature reaction flux wave
A_{3a} Amplitude of third harmonic of armature reaction flux wave
X Armature leakage reactance expressed as a decimal
B_{nL} No-load air-gap flux density
B_3 Short-circuit third-harmonic flux density
$A\ R$ Armature reaction ampere-turns per pole
F_g Air-gap ampere-turns per pole
K_i Constant dependent upon quality of stator iron
K_f Constant dependent upon frequency
w_3 Loss per cu. in. in standard iron at standard frequency at density B_3
t Thickness of pole laminations in inches
H Armature reaction per π-inch
τ_0 Stator slot pitch
P Number of poles
A Area of air-gap under one pole
V Peripheral velocity in thousands of ft. per min.
g Effective air-gap
D Gap diameter in inches
L Length of rotor stacking in inches
Q A factor dependent upon coil pitch
K_p A constant dependent upon the type of ammortisseur winding.

Abridgment of

Design and Application of Two-Pole Synchronous Motors

BY D. W. McLENEGAN* and IVAN H. SUMMERS†
Associate, A. I. E. E. Associate, A. I. E. E.

***Synopsis.**—The paper presents a brief résumé of the problems encountered in the design of two-pole high-speed synchronous motors, together with a description of how they are met. A satisfactory design is worked out. The theory of the starting winding is given briefly in non-mathematical language, and curves are presented showing the results obtained in-so-far as current and torque are concerned. It also outlines the applications in which these motors have been used pointing out both the advantages and the limitations of synchronous motors. This is followed by a description of the operating characteristics and of the method of controlling the motors.*

* * * * *

INTRODUCTION

LARGE 3600-rev. per min. synchronous motors are in demand chiefly for driving centrifugal compressors. In this application, high speed is essential in keeping down the number of stages and the weight in the compressor. Steam-turbine drives are used to some extent, and on the smaller sizes, induction motors have been used. The steam turbines are very satisfactory where a suitable supply of cheap steam is available, but frequently, the source of steam is too remote. In most cases, 60-cycle electric power is readily available.

The design of existing two-pole alternators, with their special features insuring satisfactory high-speed operation, was taken as a basis for the design of the high-speed synchronous motors described in this paper. The available turbine alternators were of the type which had laminations for the rotating elements, pressed on a steel shaft. These laminations had radial slots in which the polar field windings were wound, and the latter were held in place in the core portion by metal retaining wedges placed in suitable wedge slots just above the polar windings. The polar windings were held in place on the end portions by steel retaining rings. The mechanical and electrical designs of these alternators had been carried out together, so that smooth operation with safe mechanical stresses was assured while at the same time the flux and current densities insured heating and efficiencies within guaranteed limits. By utilizing these features, adding appropriate starting windings and making some changes in the electrical design, synchronous motors were built with starting character-

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istics comparable to those of induction motors, and with satisfactory running characteristics. It was found possible to make changes in the design of the starting windings without affecting the synchronous operation.

A squirrel-cage starting winding for a synchronous motor should not interfere with the main-pole windings in the event that the latter have to be removed for repair or replacement. In this respect, several proposed schemes for starting windings were found unsatisfactory. The method finally adopted is to cut away the teeth at the thick ends and to insert thin deep conductors in the space so formed, as shown in Fig. 1. Special slots are cut in the polar space to provide a continuous winding around the periphery. The conductors are carefully soldered to flat copper or bronze end rings, shaped to conform with the rotor slots, and fitted on the ends of the rotor core. Figs. 2 and 3 show the details of the assembling and indicate that the main field winding can be removed without interference from the starting winding. This arrangement, together with special wedges above the rotor conductors, provides excellent starting characteristics. It was found possible to get enough copper into the starting winding to give a d-c. resistance of approximately one-half of one per cent.

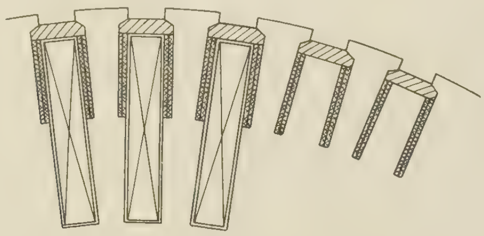

Fig. 1—Arrangement of Polar Winding, Starting Winding and Wedges in Rotor of Two-Pole Synchronous Motor

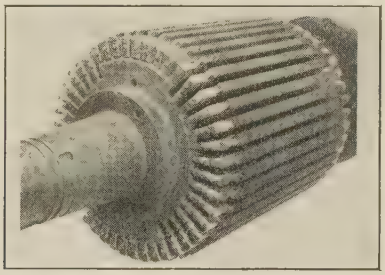

Fig. 2—View of Unwound Rotor of Two-Pole, 3600-Rev. per Min. Synchronous Motor, Showing Construction of Starting Winding

Theory

Referring to Fig. 1, it will be seen that the squirrel-cage bars are relatively deep. With this construction the effect of the leakage flux at 60 cycles is to cause an uneven distribution of current density concentrating it at the top of the slot. This causes an increase in the effective resistance of the bar and a decrease in the reactance. This effect can be calculated by well-known methods applied to rectangular bars in rectangular slots with open tops. For these motors, it was found that the effective resistance of the bars at 60 cycles was approximately twice their d-c. resistance.

We come now to consideration of a particularly interesting feature of the starting winding. In order to prevent currents from flowing axially along the rotor, it was considered necessary to make the retaining wedges above the polar winding of short sections, insulated from each other. Such currents might cause dangerous burning unless proper connections were provided at the ends of the rotor to confine them, and it is difficult to do this without interfering with the accessibility of the polar windings. Even though these wedges consist of short sections insulated one from another, they still possess the essential features of a dead conductor placed above a current-carrying conductor in a slot. That is, the leakage flux from the starting winding can induce a voltage in the wedges, causing a current to flow axially along the top of the wedge and to return along the bottom, each wedge section providing a complete circuit. Theories of this action have been worked out by various authors.[2] It was found advisable to employ two kinds of wedges, some being of steel and some of a non-magnetic metal. Various effects have been obtained by using steel and non-magnetic wedges in different alternate positions. By thus varying the proportions of the two materials, different effective resistances and reactances can be obtained. The effect of a steel wedge above the starting winding is to increase the reactance by providing a path of lower permeance for the leakage flux; and to increase the resistance by contributing a heat loss caused by the eddy currents induced in the wedge by the leakage flux. The action is like that of a tertiary winding in a transformer, except that saturation is present to a large degree in the wedge-leakage paths and modifies the results considerably.

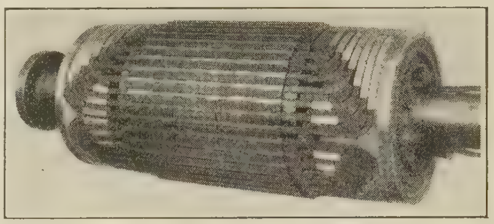

Fig. 3—Completely Wound Synchronous Motor Field before Retaining Rings are Shrunk On

Starting Characteristic Curves

Torque and current curves which were taken by test on a 1500-hp., 3600-rev. per min. motor are shown in Figs. 4 and 5 for different applied voltages. These curves clearly show how the current and torque vary with voltage and speed. It will be noted that the

2. For all references see Bibliography.

torque is maintained up to a point very near synchronous speed. The slope of the torque curves from this point to synchronism is very great, and a measurement of the slope near synchronism indicates that the d-c. rotor resistance as calculated is about one-half of 1 per cent. The fact that the torque is maintained up to a speed so near to synchronism makes it comparatively easy to synchronize the motor. A consideration of the above theory indicates that these torque and current curves could be varied materially by changing the proportions of steel and non-magnetic material in the slot wedges. Calculations indicate that at standstill the rotor resistance and reactance are each of the order of ten times the value calculated for direct current flowing in the starting winding. This shows how greatly the characteristics depend on the retaining wedges during the first part of the starting cycle.

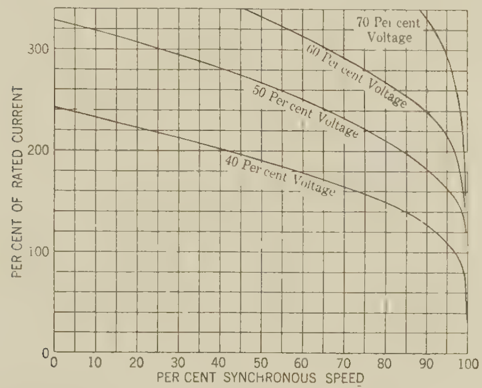

Fig. 4—Armature Current-Speed Characteristics of Two-Pole Synchronous Motor at Various Voltages

Heating

When either a synchronous or an induction motor is accelerated by means of a squirrel-cage winding from zero speed to synchronous speed, it may be readily proved that the heat generated in the rotor over the total cycle is practically independent of the construction of the starting winding. This heat energy is equal to the stored energy of the rotating parts at synchronous speed plus an amount represented by the area of a curve obtained by plotting the product of slip and load torque against time over the whole starting cycle. It was found in some actual cases that the kinetic energy of the rotating mass was equal to about 80 per cent of the total heat loss in the rotor. Thus, it is evident that a high inertia inevitably causes a heating problem which cannot be ignored. Furthermore, it is impossible to reduce the amount of heat to be stored in the rotor by any change in the construction of the starting winding.

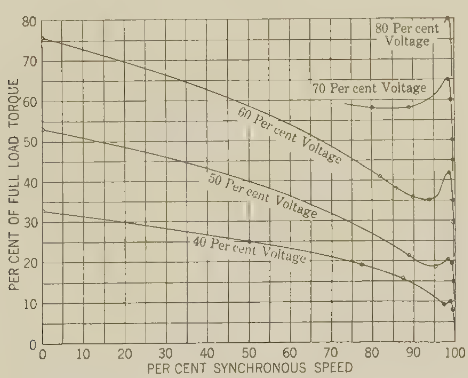

Fig. 5—Torque-Speed Characteristics of Two-Pole Synchronous Motor at Various Voltages

The temperature rise at the rotor surface can be calculated approximately by assuming the rotor to be a simple massive cylinder with heat applied at the surface. This gives a result which is independent of any method of construction of the starting winding and serves to indicate the limiting condition. The results may be modified empirically to make them fit the actual construction more closely. In this connection it is found that due to the rapid rate of heat generation, the conduction of heat into the rotor iron is the most important means of keeping the winding cool, special ventilation being of little value. In case several starting cycles occur in succession, sufficient time must be allowed for redistribution of the heat generated in order to prevent undue accumulation and local heating.

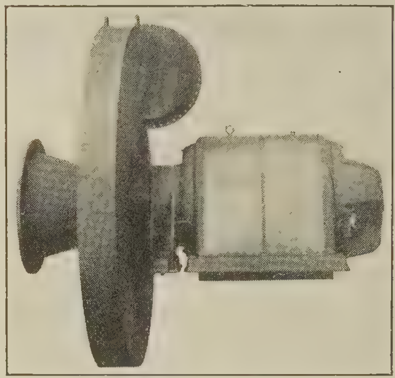

Fig. 6—1200-Hp., 3600-Rev. Per Min. Synchronous Motor, Direct-Connected to Centrifugal Compressor

Synchronous Characteristics

The synchronous characteristics of the two-pole motors are similar to those of lower-speed salient-pole machines. Since the amount of excitation required by any synchronous motor increases with the number of poles, the excitation required by two-pole synchronous motors is, of course, very small. For example, a 2500-hp. 0.9-power factor 3600-rev. per min. motor requires only 13.5 kw. Efficiencies of about 94.5 per cent have been obtained for 1250-hp. rating, and about 95.5 per cent for 3000-hp. rating, while slightly higher figures apply to larger sizes. Windage losses, which are included in calculating the efficiency, account for these results not equalling those of lower-speed machines.

Application

Several large two-pole synchronous motors have been built within the past five years, and these are operating successfully. The range of application, however, so far has been quite limited. This is due in part to the constant speed limitation of the synchronous motor, and possibly to the fact that very little information has been published on the design, construction, and operating characteristics of motors of this type.

In sizes smaller than 800 to 1000 hp. at 3600 rev. per min., the synchronous motor hardly competes with the squirrel-cage or the wound-rotor motor, unless the need

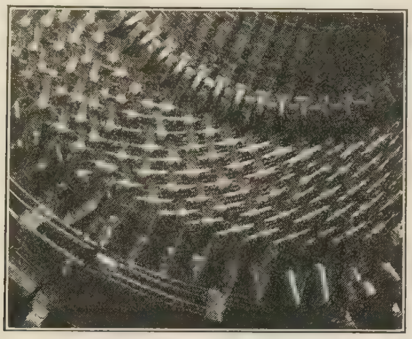

Fig. 7—Stator of Two-Pole Synchronous Motor, Showing Method of Bracing End Turns of Coils

of power-factor improvement justifies a higher first cost. With increasing size, the comparative cost of the synchronous motor improves, and this brings it into consideration for drives requiring greater power. Wound-rotor induction motors of several hundred horsepower at 3600 rev. per min. have been built, and such motors, in sizes up to 2000 or 3000 hp., have been considered. Their application, however, depends upon the solution of the problem of handling large currents at the collector rings.

For large capacities the choice is limited, therefore, to the synchronous motor, the squirrel-cage induction motor, and the steam turbine. As the power factor of induction motors is always substantially below unity, large ones must be supplemented by corrective devices to make them comparable with synchronous motors.

As nearly as we can ascertain, at the present time the largest two-pole, 60-cycle synchronous motor in operation is rated for 2550 hp. This, however, does not represent the limit of sizes that can be built with the present construction. Designs have been made for a 7000-hp., 60-cycle motor and a 4000-hp., 1500-rev. per min., 25-cycle motor.

In most of the processes to which a two-pole motor could be applied, the suitability of a constant-speed drive must be determined by the requirements of the individual installation. The two-pole synchronous motors now in service are used to drive centrifugal gas boosters, or centrifugal air compressors, in connection with sewage disposal or copper refining processes.

Operating Characteristics

Since the two-pole synchronous motors are of large ratings and necessarily have low reactance, it is important to design the control equipment to start and accelerate the motor with the lowest possible inrush of current. Considering only the motor, full-voltage starting might be used, since these motors are capable of withstanding a direct short circuit. The long end turns of the stator coils (Fig. 7) are tightly blocked to prevent movement, and severe factory tests have failed to disclose any injury to the coils after repeated short circuit at full voltage. However, the limitations of the power supply usually require reduced-voltage starting, and frequently make it advisable to use two reduced voltage steps, approximately 45 per cent and 70 per cent of rated voltage, before applying full voltage to the stator.

Fig. 8 shows the torque-speed and current-speed curves of a 1500-hp., 3600-rev. per min., 60-cycle motor, based on the use of a two-step reduced—voltage starter, together with a typical torque-speed curve for a centrifugal compressor with the discharge gate closed. Although the shape of the torque-speed curve of the motor may be modified to give lower break-away torque and higher torque at intermediate speeds, this change would result in a greater starting current. The motor torque curve is therefore made to correspond roughly with the load requirements by means of starting connections as shown in Fig. 9.

The neutral point of the auto-transformer is closed by switch *C*. After closing the line oil circuit breaker *F* and the compensator breaker *E*, a voltage approxi-

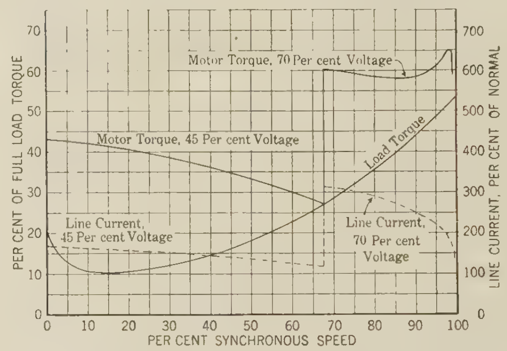

Fig. 8—Torque-Speed and Line Current-Speed Characteristics of Two-Pole Synchronous Motor, with Two-Step Compensator Starter; and Torque-Speed Characteristic of Centrifugal Compressor

mately 40 per cent of normal is applied to the motor through switch *A*, which connects the motor to the taps of the auto-transformer. After accelerating to about 70 per cent of synchronous speed, breaker *A* is opened and breaker *B* is closed, increasing the voltage to approximately 70 per cent of line voltage. If the blower load is not too great, the motor may be synchronized at this voltage by applying d-c. excitation to the field. The transfer to full-line voltage is made with the Korndorfer connection, by which an interruption of power is avoided. The compensator neutral is opened and the running breaker closed before opening the compensator breaker. During the first tap change, in

which power is momentarily interrupted, the transient inrush following the voltage change is considerably reduced by the reactance of the auto-transformer. However, when changing to full voltage it is desirable to maintain the circuit. Otherwise a high current might flow, limited only by the transient reactance of the motor. When the compensator neutral is opened before closing the line breaker *D*, there is practically no change in the voltage across the motor terminals. The upper section of the auto-transformer, serving as a series reactor, limits the voltage to the same value, or

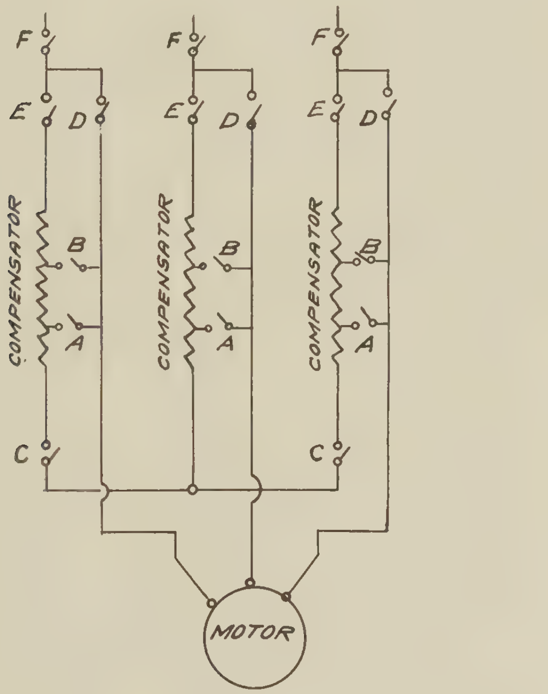

Fig. 9—Starting Connections for Two-Pole Synchronous Motor, using Two Compensator Taps, with Korndorfer Connection for the Transfer to Full Voltage

even a slightly lower value, than that previously obtained with the neutral point of the compensator closed. If the motor is synchronized before transferring to full voltage, it becomes essential when making this transfer to avoid opening the circuit. If power were interrupted, the motor speed would drop so quickly that the motor would probably be unable to re-synchronize, even though the interruption were only for half a second.

When changing to full voltage by using two taps of the compensator and the Korndorfer connection, the current drawn from the line can usually be limited to about 300 per cent of the rated current of the motor. In most installations of large two-pole motors, the limitations of the power supply require approximately this restriction of the motor current when starting.

Where such restrictions are not necessary and a high starting current is permissible, the use of a series reactor provides a simpler and less expensive control because it reduces the number of oil circuit breakers and eliminates many of the interlocks and relays required for the two-step auto-transformer starter. In Fig. 10 will be found a study of starting characteristics of the 1500-hp. motor with a two-step reactor starter. These curves are based on the use of 15 per cent external reactance, which is reduced to 8 per cent when the motor reaches 70 per cent speed. The torque-speed curve is generally similar to the corresponding curve of Fig. 8 representing starting characteristics with compensator starting. The line current, however, is considerably higher. Except in locations where an exceptionally large power supply is available, this fact would probably rule out the reactor type starter.

The accelerating duty required of a 3600-rev. per min. motor is generally quite severe and requires careful calculation. The rotor of a two-pole motor, whether synchronous or squirrel-cage, is physically smaller than that of a lower-speed motor of equal horsepower. With a given amount of heat to be dissipated in the rotor, the temperature rise is necessarily greater. Ordinarily the motors are started only once a day, or even less frequently, but provision should be made for repeated starting under emergency conditions. Where the

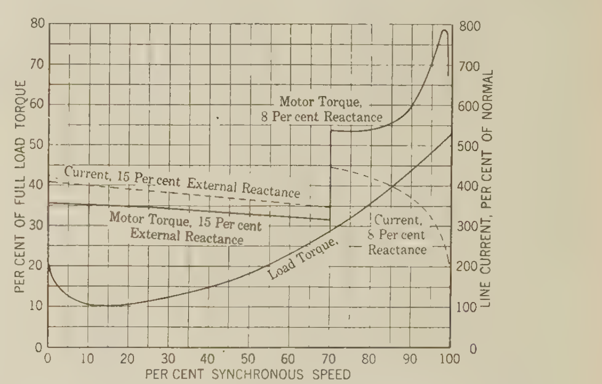

Fig. 10—Torque-Speed and Line Current-Speed Characteristics of Two-Pole Synchronous Motor with Two-Step Reactor Starter; and Torque-Speed Characteristic of Centrifugal Compressor

driven machine is a centrifugal air compressor, or a gas compressor of average design having approximately 2 lb-ft.[2] inertia per horsepower at 3600 rev. per min., motors can be designed to start twice in succession without dangerous heating of the rotor or the stator. The time interval required to retard the motor and the compressor allows some cooling as well as distribution of the heat between two complete starting cycles.

Due to the unusual torque characteristics of the motor just below synchronous speed, as previously described, the synchronizing is easily accomplished in spite of the high inertia of the average centrifugal compressor. If a rotating machine is to be pulled into step from a sub-synchronous speed, its kinetic energy must be increased by an amount corresponding to the difference

in speed, and this energy must be supplied in a time corresponding to less than one-half cycle at slip frequency. It is therefore important to reduce this slip to a minimum, to insure proper synchronizing and to limit the peak of the current inrush. Since the two-pole synchronous motor will develop approximately full-load torque when running as an induction motor at 99 per cent speed, the centrifugal compressor load can be accelerated to a slip of about one-half of one per cent, and the change from induction-motor operation to synchronous operation is made with very low current inrush.

The use of a synchronous motor on any essential machine where an outage of a few minutes may be serious immediately raises a question regarding the operation of the motor under unusual conditions such as momentary loss or dip of line voltage, or failure of excitation voltage. With suitable torque characteristics, the synchronous motor can be arranged to continue operation after a momentary loss of a-c. power, but the control must be supplemented by additional devices to accomplish this result.

In general, if due to a momentary voltage drop a synchronous motor falls more than a few per cent below synchronous speed, it will not re-synchronize upon return of voltage. However, if the d-c. excitation can be removed and the oil circuit breaker in the armature circuit remains closed, the motor can re-synchronize, provided the squirrel-cage torque at sub-synchronous speeds is sufficient to carry the load. The characteristic curve of the 1500-hp. motor, if plotted on the basis of 100 per cent voltage, would show approximately 150 per cent torque at 98 per cent speed, and 130 per cent torque at 75 per cent speed. Thus the torque near synchronous speed is sufficient to enable the motor to accelerate, upon return of full voltage, and re-synchronize with full load on the driven machine.

If the field excitation is lost, the two-pole synchronous motor can operate for a very limited time as an induction motor without overheating. Continued operation without excitation is not possible with the present designs. The use of these motors for essential service consequently requires a dependable source of direct current for excitation or an alternative source to which a transfer can be made quickly.

If the motors are designed to operate at leading power factor, then, in addition to the advantage of power factor improvement, an increase in maximum synchronous torque is obtained. The pull-out torque is increased from approximately 150 per cent of full-load torque, for unity power factor operation, to 200 per cent or more for motors operating at 0.8 leading power factor. With 200 per cent available torque at rated voltage, the motor can carry full load momentarily with line voltage as low as 50 per cent of normal.

Conclusion

The problems involved in the design and application of two-pole synchronous motors have been outlined so as to indicate the applications for which these motors are best adapted, and also to indicate their limitations. It is believed that there are other possible uses to which these motors have not yet been applied, and it is hoped that this paper will contribute to an understanding of the field of usefulness of the two-pole synchronous motor.

The authors wish to acknowledge their indebtedness to W. F. Dawson, under whose supervision these motors were developed, and by whom material for the introduction has been contributed.

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3. *Heat Losses in the Conductors of A-c. Machines*, Waldo V. Lyon, Trans. A. I. E. E., Vol. 40, pp. 1361.

4. *Starting Performances of Synchronous Motors*, H. V. Putnam, A. I. E. E., Trans., Vol. XLVI 1927, p. 39.

RADIO FADING IN THE BROADCAST RANGE

As reported in the *Technical News Bulletin* an investigation has been conducted by the Bureau of Standards to determine the factors contributing to the phenomenon known as fading. Special apparatus used in conjunction with radio receiving sets makes it possible to secure graphic records of increase and decrease of signal strength. This apparatus, sufficiently sensitive to indicate variations smaller than the ear can detect, was used with receiving systems employing different types of antennas to analyze the manner in which the waves transmitted arrive at the receiving antenna.

The factors which may cause variations in the intensity of radio waves are complex, and critical study of fading has suggested some explanations.

Graphic records of a single selected transmission were made using receiving sets identical except for the antennas. The antenna systems used in the course of the investigation were (1) vertical antenna, (2) coil antenna directed toward the station being received, (3) coil antenna with planes at right angles to the direction of the transmission path, (4) combination of coil antenna and vertical antenna connected so as to eliminate waves received directly from the station. Simultaneous records were made using two receiving sets with different types of antennas.

Examination of data from simultaneous measurements made respectively, with a vertical antenna and a coil antenna in maximum position, indicated that for stations 165 to 1500 km. distant the same sort of fading occurred simultaneously in both antennas, but that for stations 13 to 53 km. distant similar fading characteristics did not occur simultaneously.

More detail concerning these phenomena will be the subject of a future paper.

Lightning Arrester Problems

New Light from Klydonograph Studies

BY A. L. ATHERTON*

Member, A. I. E. E.

Synopsis.—*This paper outlines the present status of lightning arrester application on transmission lines and suggests future investigations to determine the most effective design and method of application. Information from klydonograph tests is presented to show that lightning arresters are needed on both high-voltage and low-voltage lines. It is suggested that present practise in both design and application has limitations which may be overcome with the result of better protection which will be economically justified.*

MUCH valuable information has been gathered in the last few years on the over-voltages which occur on transmission lines. This information has led to some radical changes in ideas of the magnitude and frequency of dangerous voltages. Simultaneously it has given a reasonable basis for determining the need for lightning arresters, their design, and their proper application.

Most of the definite information on surge values has been obtained by means of the klydonograph developed in 1923 by J. F. Peters,[1] who conceived the idea of using the Lichtenberg figures to measure surge and lightning voltages of transmission circuits in service.

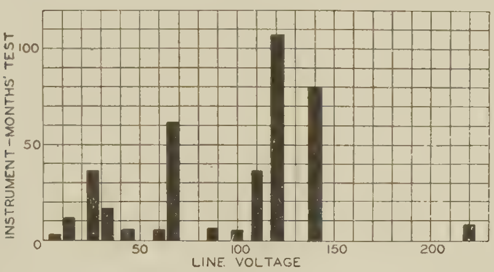

Fig. 1—Distribution of Lightning Investigations by Line Voltage

The figures had been known for years and Pedersen[2] had shown that the speed of formation is almost incredibly rapid. Peters recognized in this speed of formation one of the characteristics required in a surge-recording device. He learned, furthermore, that the size of figures varies with the voltage and that the character of the figure indicates the polarity. Subsequently he conceived and developed the klydonograph.

The device has now been in rather widespread use for four years. Much information has been gathered and this information has been made public and discussed freely.[3]

Measurements of Lightning Voltages

Klydonographs have been used in 27 investigations intended to give information as to lightning voltages. The total of instrument-months' records is 381. The distribution by voltage of line is indicated by Fig. 1, which shows that attention has been directed mainly at the higher voltages. The results are summarized in Fig. 2.

Performance of Arresters

There have been 16 tests to record and measure the performance of lightning arresters as indicated by discharge current values, with a total of 61 instrument-months' record.

In these installations, record has been made of the voltage from line to ground at the arrester terminals

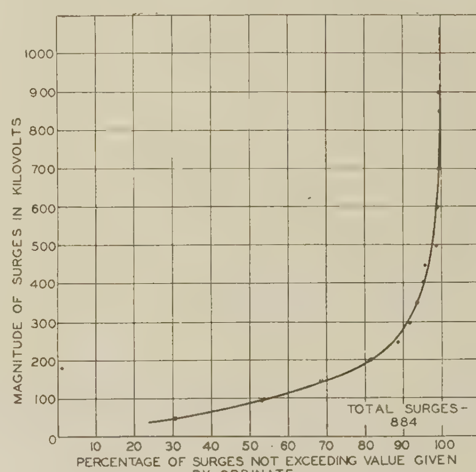

Fig. 2—Summary of Lightning Voltage Records

and of the current flow through either one phase of the arrester or through all three phases combined. About the only fact that stands out definitely is that, based on double line voltage, or 3.5 "times normal" as the lowest surge value requiring operation of the arrester, the operation is what would be expected.

Measurement of Switching Surges

In the tests to determine lightning voltages, records have been secured as to switching surges. The results

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1. "The Klydonograph," *Electrical World*, April 19, 1924.
2. "The Electric Spark," P. O. Pedersen, *Ann. der Physik*, Vol. 71 (1923) pp. 317-376.
3. *Klydonograph Surge Investigations*, J. H. Cox, P. H. McAuley, L. G. Huggins, Trans. A. I. E. E., Vol. XLVI, pp. 315-329.

Presented at Pacific Coast Convention of the A. I. E. E., Spokane, Wash., Aug. 28-31, 1928.

show that no voltages are extremely high, very few are high enough to be dangerous at all, and that these are of such short duration as to make them of no serious importance.

Dangerous Over-Voltages Occur Infrequently

Perhaps the most outstanding of the changes in ideas indicated by these results is that dangerous voltages occur only infrequently. Before these data were available, the general idea was that there might be several hundred dangerous voltages in a season at any point on the system, and that a lightning arrester, to be effective, should operate as many times. This idea was doubtless mostly the outgrowth of observation of those early forms of arresters which were adjusted after installation so that they would spark over as often as the attendant thought proper. A little consideration of probabilities, however, will show this conception to be wrong, and that the klydonograph findings referred to above were inevitable. Fig. 3 illustrates this.

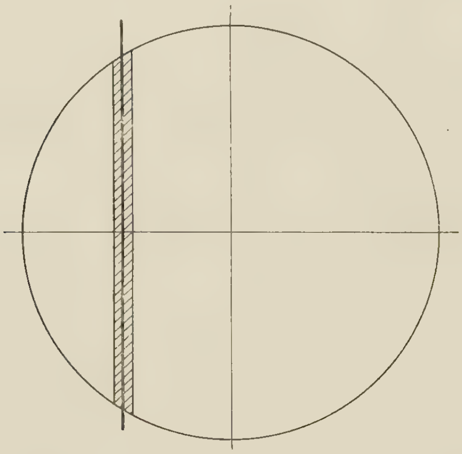

Fig. 3—Sketch Illustrating Probability of Dangerous Circuit Voltages Due to Lightning

The outer circle represents the area under observation by the Weather Bureau Station and the shaded band represents an area ¼ mi. each side of the line over which the cloud discharge must take place to give rise to a dangerous voltage.

Direct strokes are known to be rare and the only possible source of frequent disturbances would be induced charges. The circle of influence of a cloud has been shown by Norinder[4] and Peek[5] to be of hardly more than one-fourth mile radius. If we assume a generous average of 20 discharges in the clouds during a storm under the radius of perhaps 100 sq. mi. within the observation of the Bureau Station, the probability of any discharge taking place in a location to influence any one circuit to a dangerous extent is possibly one in three. This will be reduced further by the variation in induced voltage even for cloud discharges directly overhead, and for any one point on the line by the decrease in voltage due to resistance and corona losses, the effects of lightning arresters and line flashover, etc., as the wave travels. Bureau records show, for the Middle Atlantic States for example, an average of not more than 50 thunderstorm days per year. Then the number of dangerous voltages per year at any point should not be expected to average more than 5 or 10.

4. "Electric Thunderstorm Field Researches," Dr. H. Norinder, *Electrical World*, February 2, 1924.

5. *Lightning, A Study of Lightning Rods and Cages, with Special Reference to the Protection of Oil Tanks*, F. W. Peek, Jr., Trans. A. I. E. E., Vol. XLV, 1926, pp. 1131-1144.

Limitation Imposed by Line Insulation

A second point of significance is the almost controlling part played by line insulation in determining the results secured, and this seems likely to have the greatest influence on lightning arrester practise. Again, considering 3.5 times normal or double line-voltage value as the minimum surge requiring arrester operation, two-thirds of all the dangerous voltages caused line flashover. Ninety per cent of the voltages above seven times normal (four times line-to-line value) caused flashover. This is shown by Table I, which makes a comparison between (a) lightning surges requiring arrester operation which caused flashover and (b) those which did not cause flashover, based on average number of surges per station per year.

TABLE I
TIMES NORMAL

	3.5 to 4.9	5 to 6.9	7 to 9.9	Over 10
Lightning surges which caused flashover	1.46	0.75	1.18	0.51
Lightning surges which did not cause flashover	1.11	0.64	0.2	0.0
Per cent which did not cause flashover	43.3	45.6	14.4	0

Several thoughts are suggested by these figures. If it is granted that the voltage transmitted along the circuit after a flashover is so brief and of such small energy content as to be reduced to a safe value by transmission over a short distance and by the various electrostatic capacities within the station, then the protection afforded by lightning arresters is limited to one-half of those surges within the range of 3.5 and 6.9 times normal and one-tenth of the higher surges. Any tendency toward increasing line insulation to reduce flashover naturally increases the dependence on and need for lightning arresters.

Moreover, in concentrating them at the stations, we may not be using our arresters to the best advantage. This practise certainly limits the real benefits to approximately one-third of all the possible cases of need; and to make matters still worse, it concentrates this remaining sphere of benefit in the least necessary cases,—those which exceed line voltage by the smallest amount.

Present practise is based on the thought that a lightning arrester can do no good to any apparatus more than a few hundred feet away, and that any project to protect the line or to reduce line-insulator flashover by protective devices is hopeless. This is not necessarily true. Records over a relatively long period of time

have shown in one case at least that on a long line flashover is noticeably reduced for a distance of approximately two miles on each side of the lightning arresters. To determine the benefit empirically one or two installations have been made of arresters a mile or so apart along a line. To be sure, if such a scheme is to be at all practical, the arresters must be radically different from those we now know; at least for high-voltage service. But arresters for such use may be of relatively small capacity and can be designed to absorb and dissipate the energy of the surge so that transmission along the line is practically prevented and protection is automatically rendered to the stations.

Thus it might develop that by directing our protective efforts toward to the line rather than to the stations, we could add to the present benefits some reduction in line-insulator flashover with little or no increase in over-all cost.

The demonstrated limitation by line insulation suggests that the station and line insulation must be coordinated to insure so far as possible that troubles occur where the damage will be least.

Switching Surges

The fact that the switching tests have shown that dangerous voltages are not to be expected from switching operations makes a rather radical change in our conception of the function of lightning arresters. It had previously been felt that lightning arresters are required for protection against both lightning voltages and those voltages arising from switching. Arresters have been recommended and used in some cases for the protection against such voltages when actual lightning voltages are not anticipated or are so infrequent as to fail to justify the installation of any protective equipment.

All arresters have been made with special provision for easy paths between lines to take care of such voltages. This use of four elements connected in "multiplex", or the similar use of an interconnection between phases at the neutral point of the arresters, introduces some disadvantages of reduced factor of safety against abnormal conditions, and is now known to be unjustified, since the compensating advantage of shorter paths between lines is not required. Since this information has been secured, general practise in lightning-arrester design has changed and three independent elements connected from line to ground are now used. Since at least 90 per cent of all arrester failures are known to be due to some overvoltage condition, and since this change increases the factor of safety against overvoltages, it is to be expected that this is a very tangible benefit of the tests.

Indications as to the Need for Arresters

With first thought, the facts above set forth might seem to indicate that the need for protection has been over-stressed and that the use of arresters might be reduced or discontinued with safety. This, however, is not a safe conclusion as there are several cases on record in which the addition of lightning arresters has made reductions ranging from 80 per cent to 95 per cent in lightning failures of apparatus for entire systems. These are all at relatively low voltages, (below 33 kv.,) since the number of installations at high voltage on any one system is too small to yield a dependable average.

If it may be assumed that these cases establish the justification of arresters at the lower voltages, the klydonograph results add something to the conception as to the need for arresters at the higher voltages. First, it is established that dangerously high voltages do occur even on the high-voltage lines. Second, the fact that line insulation sets the upper limit of surge voltage reduces the low-voltage and high-voltage problems to close similarity for the most severe case. Third, so far as the data indicate, dangerous voltages occur as often on high-voltage as on low-voltage lines.

Because of the lack of klydonograph data at the lower voltages, no final conclusion may justly be drawn, but the indications thus far are that arresters are needed as much at high voltages as at low voltages.

Arresters Operate as per Laboratory Results

The tests on lightning-arrester operation have demonstrated one point which previously, in one sense, has been inferred only. In the laboratory it is not possible to make complete tests on high-voltage arresters at high current owing to limitations in the amount of energy readily available and complications introduced into the measuring circuit by the large mechanical extent of the required testing equipment. Tests have been made to demonstrate that within the range which can be measured accurately, the characteristics of the sectionalized type of lightning arrester are directly proportional in voltage to the number of sections in series. This is as would be expected and the industry has continued making and using very high-voltage arresters beyond the range which has been definitely tested, on the basis that this relation holds throughout. Our assurance of this assumption is increased by the facts that the arresters have operated whenever the voltage recorded was high enough to warrant an operation and that the current values have corresponded closely with what would be expected from the voltages and the characteristics of the line.

The Present Problems

If these tentative conclusions are correct, then, although we may justify lightning arresters as now made and used, present practise limits their possible usefulness to a small fraction of the cases of real need. There is grave doubt as to whether the field of usefulness can practicably be extended to cover all the need, but this doubt is far from being a certainty. There can be no justification for failing to attack the problem even though the chances of success may seem slight, since the possible gain is so great and since no alternative has proved to be effective.

Two possible approaches suggest themselves: (1)

extension of empirical trials in service, and (2) determination of the basic data necessary to evaluate the possibilities. Both, it seems, should be tried.

The extension of the trials of arresters at intervals along the line has in its favor that it will begin to secure some results immediately and that it will stimulate the design and development effort necessary to make the scheme practicable. Against this plan is the fact that there is some expense involved and that it is far from certain that it leads to the final solution.

The approach by study of conditions deserves favor in that it will ultimately point to the correct solution. Against this are the facts that it will be very expensive and that it will require some years to make the tests, after which schemes for connection must be developed.

As valuable as the klydonograph has been, it appears that it is not going to give us all we need to solve the lightning problem. Voltage-time relations for lightning voltages must be determined and it may be necessary to eliminate the flashover limitation by over-insulation of some test circuit before the final answer is secured.

The cathode ray oscillograph opens the way to begin this phase of the problem; in fact, the work is already under way on a small scale. But very much broader tests are required. Data should be secured simultaneously in many locations distributed over that part of the country where transmission is required and where lightning troubles are likely. The efforts should be coordinated and the results gathered together for recording, analysis, and dissemination. This work cannot be left to one unit of the industry or it will not be done. It is a problem for the whole industry and requires the coordinated effort of operators and manufacturers alike to solve it.

Abridgment of

An Amplifier to Adapt the Oscillograph to Low-Current Investigations

BY SIGMUND K. WALDORF[1]

Associate, A. I. E. E.

***Synopsis.**—There has been need in several fields of electrical engineering research for a means to study time relations, wave forms, and similar phenomena where only infinitesimal currents are obtainable. The limitations and advantages of several possible methods of investigation are compared briefly, and the conclusion reached that the ordinary oscillograph can be most profitably adapted to such work.*

The best form of vacuum tube amplifier for the work is then discussed, followed by a description of the steps taken in the design of a suitable resistance coupled amplifier. This amplifier is then described.

The results of tests showing quality of reproduction are given in the form of oscillograms and a characteristic curve. The recommended procedure to be followed and the necessary precautions to be observed in the use of the amplifier are given with a short discussion of the abilities and possibilities of the oscillograph in its widened field of usefulness.

* * * * *

Introduction

The ordinary type of oscillograph, operating on the D'Arsonval principle, has proved of great value in many fields, but the currents required to give workable deflections are so large as to restrict its use to cases where the available currents are greater than approximately a twentieth of an ampere. To obtain fairly large deflections, about a tenth of an ampere is necessary for alternating currents and almost a fifth for continuous currents. For low-current investigations where the currents are less than these values one must look around for other means or apparatus to meet the requirements. The cathode ray oscillograph or the Einthoven string galvanometer might be mentioned, but they have several serious limitations for engineering problems for which the usual type of oscillograph has desirable characteristics. For combined sturdiness, ease of operation, transient recording, simultaneous multiple recording, and general utility, the oscillograph far surpasses these other instruments.

Thus it has been thought worth while to adapt the oscillograph to small currents by means of a suitable vacuum tube amplifier. Such amplifiers are in common use for many purposes, so that their various forms and principles of operation are now widely known. The particular problem in this case was to obtain perfect reproduction over the entire frequency range of the oscillograph, a requirement calling for the careful selection of the proper circuit and careful subsequent design and construction. An amplifier circuit utilizing transformers cannot be expected to give perfectly equal amplification of all frequencies over a wide range. This can be predicted from theoretical considerations and has been shown experimentally in the unpublished effort of another investigator using a resistance coupled amplifier with a transformer in the output circuit. The

1. Graduate Student in E. E., Johns Hopkins University, Baltimore, Md. *Initial and Best-Paper prize paper, presented at the Meeting of the Baltimore Section, District No. 2, Baltimore, Md., April 22, 1927.*

purpose of this transformer was to obtain sufficient oscillograph current without requiring excessive plate current from the output vacuum tubes.

With this in mind, the resistance-capacity coupled and the straight resistance coupled amplifiers are the only ones that can be expected to give faithful amplification over a wide range of frequencies; so these are the only two seriously considered here. The resistance coupled circuit was the only one found to be entirely satisfactory for all frequencies for which the oscillograph can be used, and it has the additional advantage that it amplifies continuous currents as well as alternating. Therefore the amplifier which has been built and is described in this paper will meet all frequency conditions for which the oscillograph is applicable.

The Amplifier

Extensive tests with a two-stage resistance-capacity coupled amplifier indicated that this type of amplifier circuit would not give perfect reproduction over the desired range of frequency, so a plain resistance coupled amplifier was designed and built according to the plan of Fig. 6.

This plan for the amplifier has the input impressed on the grid of a Western Electric 102-D tube and the plate circuit of this tube acting on the grids of six Western Electric 104-D tubes with their grids, filaments, and plates connected in parallel. The oscillograph element is connected directly into the combined plate circuit of these 104-D tubes. As no transformers were to be used anywhere in the circuit because of possible distortion, the 102-D tube was chosen for the

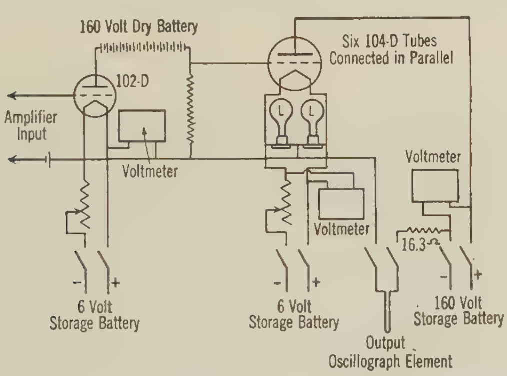

Fig. 6

first stage for its high amplification factor, and the 104-D tubes in parallel for the second stage for their high-current output at relatively low plate voltage. The power requirements of both these types of tubes are not exceptional and can be handled easily.

The added plate resistor of 16.3 ohms was found necessary to help straighten the characteristics of the 104-D tubes. As it must carry as much as a quarter ampere, it is made of No. 24 B. & S. double cotton-covered advance wire, wound non-inductively on a wooden spool. A further aid in straightening the characteristic is the potential divider arrangement of the two incandescent lamps in series across the tube filaments. When under operating conditions the maximum plate current is drawn from each tube, the plate current is of the order of seven per cent of the normal filament current. If all this flows into the filament at one end there will be excessive heating of the filament at this end. There will then exist an appreciable change of the filament temperature with change

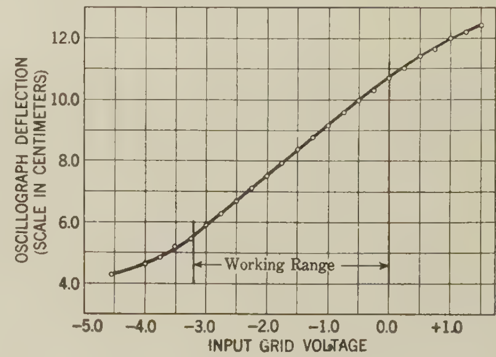

Fig. 7

in plate current, causing an irregular amplifier characteristic. Providing two parallel paths for the plate current reduces this effect to a minimum by giving a more even division of the current between the two ends of the filament.

Using a potential divider of two 200-watt, 120-volt, Mazda C lamps as shown actually considerably improved the operation of the amplifier. Of course besides having the described effect, these lamps are additional resistance in the output circuit, thus serving a double purpose. The lamp resistance varies with the applied voltage, but with the constant filament voltage of 4.5 volts maintained, their combined series resistance was found to be fixed at about 15 ohms.

Tests of Reproduction

Under all possible conditions the performance of an amplifier must necessarily be the criterion of its worth. This particular amplifier has been tested under a number of differing conditions and has been found to have excellent properties.

As the amplifier is to work with the oscillograph, all tests were made considering the combination as a single unit designed to record low-current phenomena. The conditions on the oscillograph, as well as those on the amplifier, were kept under close observations. For all tests the tensions on the oscillograph elements were kept at five ounces, and when observations were made, the galvanometer field current on the oscillograph was kept at the rated saturation value of 0.35 ampere or slightly above.

Resistance coupling is a d-c. amplifier circuit and permits of taking a static characteristic curve. This was done, and the result is given in Fig. 7, the

sensitivity of the output oscillograph element being 40 milliamperes per centimeter deflection. As can be seen, straight line reproduction is obtained for grid potentials between zero and − 3.2 volts, with a total change of oscillograph deflection of 5.2 centimeters. With a grid bias of − 1.6 volts on the input, operation takes place in the middle of this range. In tests where the input wave form is unknown, the amplitude is kept well within these limits so that any peaks present will not be distorted by being beyond the straight portion of the curve.

To test the quality of reproduction of the amplifier

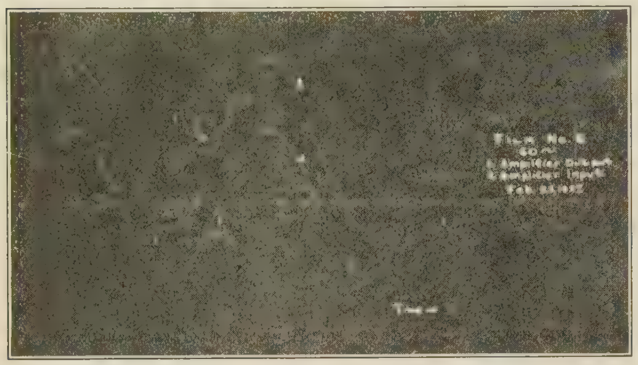

FIG. 8

with alternating currents it is necessary that the input wave form be recorded as well as that of the output, and that the input as indicated by the input oscillograph element be absolutely the same as that impressed on the amplifier input. To attain this, a high-grade laboratory resistance box was placed in

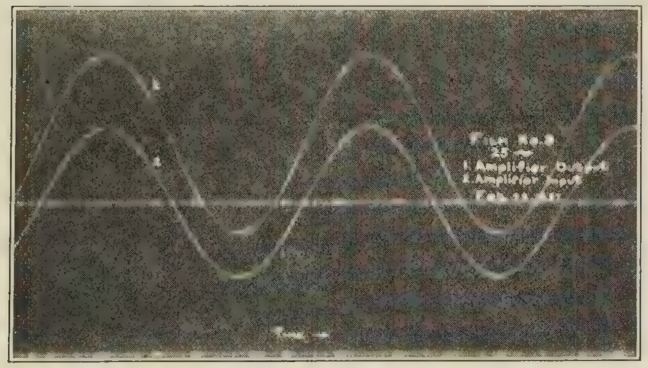

FIG. 9

series with the oscillograph element recording the input current and the amplifier input connected to the terminals of this box. The amplitude of the input wave was regulated by variation of the current through the input oscillograph element, and that of the output wave by variation of the value of the series resistance across which the input was connected.

In the tests of reproduction, a resistance R_G was inserted in the input grid circuit and was given values from zero to 105,000 ohms. If the grid currents were of the same order of magnitude, or even somewhat smaller than the currents to be amplified, there would be distortion introduced when the grid circuit impedance is made very high. The effect of this grid impedance is not noticeable for any values within these limits. The oscillograms shown are with this high resistance inserted. This amount was used because the author was most interested in the behavior of the amplifier when the currents to be amplified are of the order of five to ten microamperes, or larger. With these small currents, the necessary circuit resistance to be inserted to obtain proper input grid potential variations is about of the stated value. If it is desired to amplify currents smaller than this, or the available voltage variation is too low to give good oscillograph amplitude, a third stage identical with the 102-D stage and acting on this stage with the necessary change of grid bias may be placed on the amplifier. Under such conditions the input voltage variation need be only little more than a third of a volt and the amplified currents possibly of the order of a microampere for maximum amplitudes.

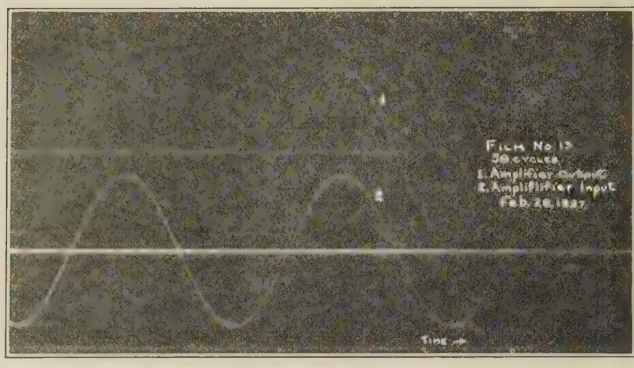

FIG. 10

Figs. 8 and Fig. 9 show the quality of reproduction of the amplifier with a sine wave impressed. The straight lines on these figures are the zero lines of the input voltages; no zero lines were taken on the output. The amplitudes of the output waves are five centimeters, which is about the limit for perfect reproduction.

Fig. 10 shows the reproduction of an a-c. wave with ripples present on the peaks. Fig. 11 shows a fairly smooth wave taken at a higher frequency where the wave forms of the cycles vary. The amplitude on Fig. 10 is four and a half centimeters between opposite peaks; that on Fig. 11 is four centimeters.

Fig. 12 is of special interest, as this is a record of a transient phenomenon of very irregular wave form. As the form of the wave was unknown when the record was being made, the amplitude of the light spread of the oscillograph was widened by increased resistance, across which the input was connected until it was about four centimeters. This allowed ample room on the straight portion of the amplifier characteristic for any peaks that might have been present and not apparent on the stationary ground glass scale. Then the film

was exposed and the record obtained. The arrow points to a short oscillation which occurred and which was reproduced very well. As this oscillation is at about 4500 cycles per second and is amplified satisfactorily, it is indicated that the amplifier will take care of all conditions which the oscillograph itself can handle properly at the higher frequencies.

A careful study of these tests shows that the amplifier described gives identical reproductions and that it is competent to extend the range of the oscillograph

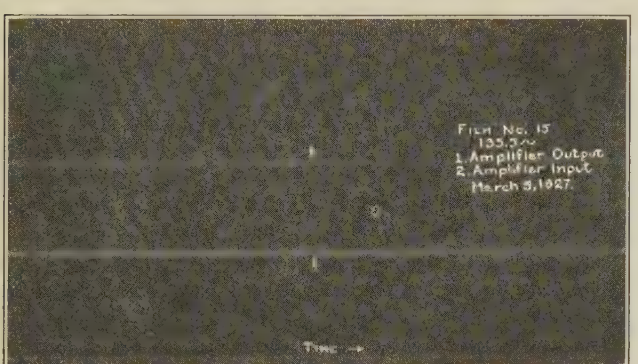

Fig. 11

down to five or ten effective microamperes at one effective volt on alternating current, or slightly higher voltage on direct current.

Application

A few words should be said concerning the actual use of the amplifier. It is believed that it has been reduced to its simplest possible form and that apparatus requiring the operator's attention is at a minimum. The observations and tests described have been made with-

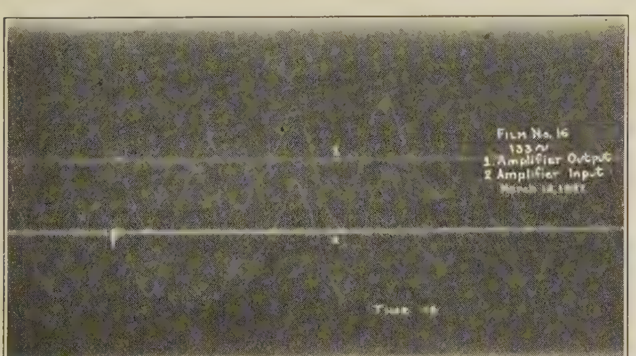

Fig. 12

out difficulty by a single operator. The ordinary care exercised in the use of the oscillograph and of vacuum tubes should be sufficient for the proper operation of the combined amplifier and oscillograph.

An instance of the usefulness of the amplifier is given in Fig. 14, which is a test made to observe the commutator ripple of a high-voltage d-c. generator when shunted by condensers. Some research was in progress for which it was desirable to determine what could be done to remove the ripple of a 15,000-volt machine. For observation of the ripple, the oscillograph was the logical means, but as the oscillograph ordinarily requires about a tenth of an ampere for such indications, it is difficult to obtain and handle resistance for this current and voltage to be placed in series with the oscillograph element. So a suitable resistance taking about three milliamperes at the given voltage was connected across the generator and the amplifier input connected to a four-dial resistance box in the tail circuit. For this work a negative input grid bias of about three volts was used and the input so connected as to make the input potential more positive for increased applied voltages. The distance between "1" and "2" on Fig. 14 represents 5800 volts. In this manner the oscillographic study was made very easily at a number of different voltages with the amplifier, which otherwise would have been very troublesome.

Conclusion

It was the purpose of this work to develop a simple and convenient method for making oscillographic studies of high-voltage and low-current waves and similar phenomena—one which could be depended upon to give perfect reproduction of very small currents, pre-

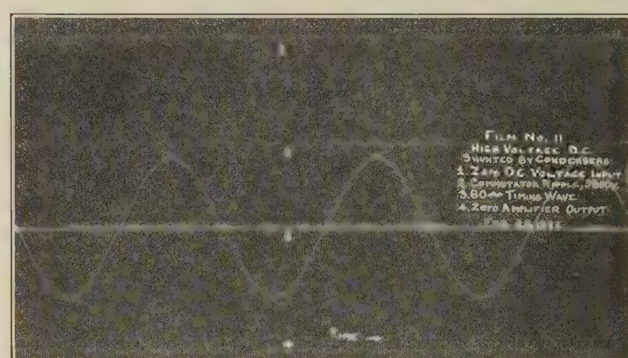

Fig. 14

serving them in their true phase relations as well as in form. It is felt that this has been accomplished and that the amplifying oscillograph, if the combined amplifier and oscillograph may be so called, should prove a useful instrument in electrical engineering research. The oscillograph, already valuable in a wide field, has now had its range extended down to currents of about ten microamperes or less.

The author wishes to acknowledge his indebtedness to the Department of Electrical Engineering of the Johns Hopkins University for the use of its apparatus and of its laboratory, where this development has been accomplished. He also wishes to express his appreciation to those at the University who have shown interest in the progress of the work and who have made suggestions from time to time.

Abridgment of

Electrophysics

ANNUAL REPORT OF THE ELECTROPHYSICS COMMITTEE*

To the Board of Directors:

The personnel of the Committee and its general policies have been practically the same as during the preceding Institute year, so that this report is essentially a continuation of the last year's report. A steady endeavor has been made during the year to connect some practical engineering problems with the achievements and efforts of modern physics, both experimental and mathematical. In these endeavors we have been materially assisted by the two liaison representatives of the American Physical Society, authorized by the Board of Directors in 1927. As a further step in the same direction, the Committee arranged for a general lecture on *The Nature of the Electric Arc*, which was ably delivered by Professor K. T. Compton at the 1927 Summer Convention in Detroit.

The success of this lecture led to an authorization of another lecture at the 1928 Winter Convention. The subject of this lecture was *The Earth's Electric Charge*, and it was delivered by Dr. W. F. G. Swann of the Bartol Research Foundation. This lecture was also quite successful, and as a result a lecture on geophysics, by Dr. C. A. Heiland, has been scheduled for the forthcoming convention in Denver. The Committee recommends that a lecture on some topic in "border sciences," such as physics, chemistry, mechanics, or mathematics, be scheduled at all our large conventions, as a stimulus to young engineers in fostering the progress of the art and as a preventative against in-breeding. In particular, for the next Winter Convention, the Committee suggests a topic on spectrum analysis in application to the constitution of the stars. During such a lecture, much of the latest progress in the atomic structure could be explained on a specific problem.

Electrical Discharges in Gases

Disruptive Discharges. A simple relation for determining the voltage across a spark-gap during the course of breakdown has been given, but the constant entering into this relation has been found to vary widely under different conditions of test. (Toepler, Mueller, *Arch. f. Elektrotech.*). Cathode ray oscillographic study of spark-gaps also gives results incompatible with the Toepler spark constant (Tamm, *Arch. f. Elektrotech.*). Photographs of incompleted sparks indicate the need for modification of the Townsend sparkover theory for high voltages at atmospheric pressures. (Torok, A. I. E. E. Jl., Mar. 1928). The distortion of the electric field by a space charge in the early stages of the formation of the spark may be important (Loeb, *Journ. of Franklin Inst.*). Whether negative ions are generated near the cathode by collisions of positive ions with gas molecules, or by radiation acting photoelectrically upon the cathode, has actively been debated. (Taylor, Townsend, *Phil. Mag.*). Experiments on "three-point spark-gaps" favor the photoelectric action. (Morgan, Thomson, *Phil. Mag.*). Lowering of the sparking potential under sustained high-frequency applied voltage has been observed. (Reukema, A. I. E. E. Jl., Dec. 1927).

Corona. Further studies on the mechanism of corona, bringing out the part played by space charges, have been made (Carrol & Lusignan, Peek, A. I. E. E. Jl., Dec. 1927). A quantitative theory giving excellent checks with observations has been developed for the d-c. corona. (Holm, *Arch. f. Elektrotech.*)

Arcs. There has been great interest in the theory of the electric arc. The possibility of arcs with cathodes too cold for thermionic emission is being accepted. Application of the heat balance method of determining the proportion of current carried by electrons from the cathode does not agree with the thermionic theory of the cathode. (Compton, A. I. E. E. Jl., Nov. 1927). In applying the heat balance method, the experimental results of Van Voorhis (*Phys Rev.*) on the heat of neutralization of positive ions are important. The view that electrons are drawn from the cathode by very high electrostatic gradients maintained by space charges is being favored (Compton, Prince, A. I. E. E. Journal, July 1927). In this connection, however, Rosario (*Journ. of Frank Inst.*) describes experiments casting doubt on the ability of electric fields, of the order of magnitude here postulated, to draw electrons from a cold cathode.

Ferromagnetism

Among the advances which have been made in the field of ferromagnetism during the past year are the following:

1. Further studies of the magnetization and magnetostriction of single crystals of iron (Dussler and Gerlach) and of nickel (Kaya and Masiyama, and

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W. F. G. Swann A. P. Wills

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928. Complete copies upon request.

Sucksmith, Potter and Broadway), show the dependence of these properties on crystallographic direction.

2. The permeability of iron has been reported in two papers (Wait, and Gutton and Mihul) to have no peculiarly small value in alternating fields of radio frequencies, contrary to the results of Wwedensky.

3. Magnetic viscosity, the time lag in mangetization, has been investigated experimentally by Lapp.

4. DeWaard in a mathematical treatment has attempted to account for ferromagnetic properties as dependent on crystal form and crystal lattice.

5. Some evidence has been obtained by X-ray analysis of films of iron in magnetic fields as to the ultimate nature of magnetism. T. D. Yensen, *Phys. Rev.*, Vol. 31, April 1928, p. 714.

6. An X-ray analysis of thin films of electrolytic iron gave results supporting the hypothesis of the atomic nature of magnetism. A circular X-ray diffraction pattern resulting from the randomly oriented minute crystals of iron in a film were examined with the film unmagnetized and also magnetized. No difference in the pattern due to magnetization could be detected, a result apparently explicable only on the assumption that the fundamental magnetic unit is atomic in character.

7. A notable contribution to the literature of ferromagnetism, of particular interest to electrical engineers, is T. F. Wall's book on Applied Magnetism.

8. A new method of obtaining strong magnetic fields has been described by P. Kapitza, *Roy. Soc. Proc.*, 115, Aug. 1927, p. 658.

Radio and Electro Acoustics

The following were live topics under review during the year:

A. *Radio*:

1. Propagation phenomena; effect of solar activity, ionized regions, Heaviside layer, etc., on radio transmission;
2. Precision measurement of frequency;
3. Television without wires;
4. Radio on trains;
5. Miscellaneous apparatus, such as field intensity sets, tube generators, etc.

B. *Acoustic matters*:

1. Super-sonic waves in gases, liquids, and solids;*
2. Analysis of vowel and other sounds by means of technical devices;
3. Bessel and exponential horns for sound power;
4. Loudspeaker and receiver tests;
5. Sound transmission through building materials.

Magnetic and Electrostatic Fields

Magnetic field distribution has been studied in application to various problems in electrical machinery, such as reluctance, wave form of e. m. f., pole-face losses, inductance, armature reaction, etc.

An important advance in our knowledge of magnetic fields is the work of Dr. Th. Lehmann. In the *Revue Generale de l'Electricite*, Dec. 24, 1927, he discusses the effects of pole saturation and interpolar iron on interpolar flux, considering as before the non-lamellar character of the field. The non-lamellar field, also treated in some recent articles in the *General Electric Review*, and *Electric Journal*, is related to eddy-currents, which were considered by Roth, Schenkhag, and Strutt. Roth has discussed the case of slot-conductors in the *Revue Generale de l'Electricite* of Sept. 27, 1927. H. Schenkhag and M. Strutt have discussed the flux distribution in busbar conductors, in the *Archiv für Elektrotechnik*. Dr. E. Weber, in the *Archiv. für Elektrotechnik* of Nov. 17, 1927, has reported on the effect of the pole-shoe shape on flux distribution and wave form of e. m. f. Dr. Th. Lehmann has pointed out a needed modification of the "Minimum-Reluctance Rule" in computing mechanical forces of the magnetic field.

The electrostatic field of force within high-tension transformers has been investigated by Dr. J. Labus in the *Archiv für Elektrotechnik* for Nov. 3rd, 1927. The method used was that of the functions of a complex variable, and several new cases have been solved. W. Wittwer in the *Archiv* for April 7, 1927, reported on a combined mathematical and experimental method, by which he has studied the correlation between the breakdown strength and the geometrical factor, for the cases of insulation bounded by electrodes with sharp edges.

Dielectrics

In view of the existence of a Committee on Electrical Insulation of the National Research Council (Professor J. B. Whitehead, Chairman) with which the writer of the present report has kept in close touch through several members common to both committees, the activities of the Electrophysics Committee in the field of dielectrics so far have mainly consisted in cooperating with the other committee. Those interested in details of various researach projects and actual investigations in the field of dielectrics, should consult the Annual Reports of the Committee on Electrical Insulation. Among the principal problems under discussion are the following: (a) Dielectric phase difference, loss and absorption; (b) ionization, polarization and physical theories; (c) dielectric strength and breakdown; (d) dielectric constant; (e) resistivity and conductivity; (f) flashover; (g) physical and chemical changes due to electric stress; (h) properties of particular materials as related to manufacturing processes; (i) special problems on the insulation of communication systems.

A number of experimental researches on dielectrics are being conducted at various universities, as will be seen from the following partial list:

*By super-sonic waves are meant longitudinal vibrations similar to sound waves, but of frequencies much beyond the audible range, reaching as high as 400,000 oscillations per second and beyond. Some striking effects of such waves, as well as practical applications, have been demonstrated by Prof. R. W. Wood of Johns Hopkins University.

Harvard University, under Prof. C. L. Dawes—"Gaseous Ionization in Impregnated Paper Insulation."

Massachusetts Institute of Technology, under Prof. V. Bush—"The Properties of Papers used for Impregnated Paper Insulation."

Johns Hopkins University, under Prof. J. B. Whitehead—"Influence of Variations in Drying and Evacuating Processes on the Properties of Impregnated Paper."

University of Wisconsin, under Prof. Edward Bennett—"Relation between Dielectric Losses and Anomalous Charging Current."

University of Illinois, under Prof. E. B. Paine,—"Ionization in High-Voltage Cables."

The Johns Hopkins University, under Prof. W. B. Kouwenhoven,—"Phase Difference in Air Condensers."

University of Wisconsin, under Professor Edw. Bennett,—"Properties of Dielectrics."

The Johns Hopkins University, under Prof. J. B. Whitehead,—"Fundamental Study of Dielectric Absorption and of Waxes and Oils."

Cornell University, under Professor V. Karapetoff,—"Study of Oils used in High-Tension Cables."

These researches are supported for the most part by the National Electric Light Association, Association of Edison Illuminating Companies, the Engineering Foundation, or individual public utilities.

Some Points of Contact Between Electrophysics and Electrical Engineering

A pure physicist usually studies whatever interests him most, or for whatever problem he has the necessary experimental and mathematical equipment. On the other hand, an applied physicist, or an engineer working on the border line between engineering and physics, is naturally limited to those topics which promise a more or less immediate application. The following list indicates some of such topics, although undoubtedly there are many more not included in it. It is hoped that this list may stimulate some younger engineers to undertake further "importation" of methods and results from the domain of physics into that of engineering.

Arcs; their theory, spectroscopy, phenomena at the cathode, stability, range of voltage, distribution of potential.

Atmospheric Electricity; theory of; methods of measurement; prediction of disturbances; thunderstorms, aurora borealis, ionized conducting upper layer of the atmosphere, the nature of terrestrial magnetism.

A-c. Bridges; various types, sources of power, detectors, inaccuracies, shielding.

Bushings for Extra-high voltages; theory of stress distribution; design, experimental investigation of stresses, and safety against flashovers.

Cables; capacitance, heating, insulation resistance, ionization, study of oil and paper, stresses, joints, sheath and armor.

Capacitance; computation of; for lines, cables, plates, spheres, antennas, and irregular shapes. Measurement of capacitance in difficult cases; design of condensers for extra-high voltages and large capacitance.

Cathode Rays; their theory, production, measurements, application to oscillograph, penetration through matter, production of X-rays.

Circuits; general theory of; Heaviside's operational calculus; Carson's theories.

Conduction of Electricity in gases, liquids, and solids; fundamental theories, crucial experiments.

Contact Phenomena; resistance, e. m. f., heating, etc.

Corona; as a particular case of ionization and conduction in gases; study of the individual layers of ionized gas, from the electrode out; space charge, mobilities of ions, etc.

Dielectrics (topics discussed above).

Discharges; glow, brush, streamers, sparkover; their spectroscopy; character of ionization, numerical relationships.

Electromagnetic Theory; circuit equations, propagation of disturbances in dielectrics, dispersion; vector calculus operators; eddy currents in large conductors.

Electrometers; uses, theory, improvements in construction to facilitate setting up and use.

Electrons and Positive Ions; the fundamental properties: mass, charge, velocity, equivalence to a current, magnetic and electrostatic fields produced by such ions; action of external fields on an ion; relativity correction for mass; statistical mechanics of ions and neutral particles of matter in a mixture; reflection, ionization, diffusion, mobility, space charge; clustering; different kinds of collisions; refraction from crystals.

Fields, Electric and Magnetic; theory of fields, mapping out a field experimentally; theoretical plotting of lines of force and of equipotential surfaces; extension to three-dimensional problems.

Heat conduction in electric conductors and in dielectrics; accurate measurement of temperature distribution in electrical apparatus; theoretical investigation of heat flow in connection with iron loss and dielectric loss.

High-Voltage Tests; development of the technique of impressing a voltage of desired magnitude and wave form (steady, sinusoidal, impulse, etc.) and of accurately measuring its effect.

Inductance; measurement and theoretical computation of, for coils, lines, cables, and conductors of irregular shapes; effect of frequency.

Lichtenberg Figures; a detailed study of their production and properties; development of more sensitive figures which would clearly differentiate between the magnitude of an impressed voltage and its wave form.

Lightning Protection; development of laboratory tests for lightning arresters under conditions approximating actual service; measurement of actual line disturbances; production of materials and combinations with a smaller time lag, for lightning arresters; valve action; effect of a resistance in series with a protective device.

Measurements of amplification, current, frequency, voltage, power, phase angle, resistance, inductance, capacitance, time intervals, lengths, etc., when these quantities are extremely small, extremely large, of transient nature, or have to be observed under difficult conditions. Measurement of quantities introduced by the modern electronic physics, such as ionic currents, quanta, radiations, spectral lines, photoelectric effects, etc.

Oscillations; generation of electric oscillations; suitable circuits; theory of complex oscillations; the matrix theory of spectral lines.

Oscillographs; further development of types to extend the present range of usefulness.

Photoelectricity; theory of; measurement of the quantities involved; development of better photoelectric cells; new applications of such cells.

Piezoelectricity; theory, applications, apparatus, measurements.

Quantum Theory. This theory is the foundation of modern physics, and one not familiar with its premises and formulas is cut off from reading most modern books and periodicals in physics and from following the progress of the art.

Spark-Gaps and Sparkovers. Much remains to be done in ascertaining the behavior under various conditions of gas pressure, temperature, and moisture. A more rational theory, in terms of electronic ionization, photoelectric effect, and space charge is also needed.

Spectroscopy is proving to be a very powerful tool in various physical studies, so that it is of importance for engineers to become familiar with its methods, theory, and nomenclature, such as band and line spectra, arc and spark spectra, relative intensities of lines, superfine structure, terms, series, excitation by collisions and by radiations, etc.

Structure of Matter. In most cases the present knowledge of intra-atomic phenomena is insufficient to account for the complex phenomena with which engineers are concerned, making an empirical approach unavoidable. Nevertheless, a rapid progress is being made in atomic physics, and new methods and concepts are being introduced, such as quanta, relativity, the matric theory, the wave mechanics (Broglie-Schroedinger), etc., so that engineers working on the border-line of physics should keep posted at least on the general trend of the progress, introducing new concepts and terminology into their work as much as possible.

Thermionics; emission of electrons from hot bodies; theory and methods of measurement.

Transient Phenomena; although the theory of many transients has been thoroughly investigated, yet there are many others of greater complexity or of shorter duration, for which we have neither a satisfactory theory nor proper recording devices.

Vacuum Technique. More and more electrical measurements have to be performed in a high vacuum or under reduced pressure, and it is of importance to continue developing pumps, pressure gages, temperature and moisture control, elimination of impurities, etc., to make such measurements simpler and more accurate.

Waves and Surges along wires and in dielectrics acquire greater and greater importance both in power engineering and in communication work. Their experimental investigation is for the most part quite difficult, for they are transients in time and in space, whereas our recording devices are stationery and measure transients in time only. The theory of such transients is also quite involved and requires a knowledge of some new and advanced branches of mathematics and physics. Nevertheless, the electrical profession as a whole will have to develop experts capable of dealing with such problems, and a concerted effort should be made without further delay, possibly beginning with the best colleges of engineering.

Wave Mechanics. At the present writing, much of theoretical atomic physics is being re-written on the basis of the so-called "wave mechanics," introduced by de Broglie and Schroedinger. If this point of view continues to be successful, the next generation of engineers may have to deal with concepts entirely different from ours. Even such well-established principles as electronic orbits within an atom begin to be looked upon as mere abstractions of the human mind rather than physical realities. For a general exposition of this theory see H. F. Biggs, "Wave Mechanics," *Oxford University Press*, 1927; K. K. Darrow, *The Bell System Technical Journal*, 1927, Vol. 6, p. 653; W. F. G. Swann, *Journal of Franklin Institute*, 1928, Vol. 205, pp. 323 and 519.

X-Rays. The importance of X-rays in various industries increases each year, so that many more electrical engineers should become familiar with the theory of these particular radiations, as well as with the handling of the apparatus and specimens. Moreover, X-rays are proving to be a powerful means of studying the structure of matter, and the constitution of the atom, particularly in its inner parts adjacent to the nucleus, which latter remains the least known part of the atom.

VLADIMIR KARAPETOFF, *Chairman.*

The water of indoor swimming pools can be kept completely sterile by exposure to the rays of ultra-violet electric lamps, according to a series of tests recently carried out by the Detroit Athletic Club. It was found that the rays not only killed all germs in the water, but that they did not add color, taste or irritating qualities to the water.

Health experts and sanitary engineers have long held to the theory that bodily contact with germs usually found in pools unexposed to the sun's rays is little less dangerous than drinking impure water. The new application of ultra-violet lamps promises to do away with this hazard.—*Utility Bulletin.*

Abridgment of

Instruments and Measurements

ANNUAL REPORT OF THE COMMITTEE ON INSTRUMENTS AND MEASUREMENTS*

To the Board of Directors:

The Committee on Instruments and Measurements is at present studying several pertinent phases of electrical measurements through standing subcommittees as follows:

1. Measurements of Variable Power and Large Blocks of Energy
2. Dielectric Power Loss and Power-Factor Measurements
3. Measurement of Non-electrical Quantities by Electrical Means
4. High-Frequency Measurements
5. Remote Metering

The present status of these is as follows:

Variable Power and Large Blocks of Energy

This subject was covered in the report of the committee for 1925-26. Additional matter for future report is being collected by the subcommittee under the chairmanship of T. E. Penard.

Dielectric Power Loss and Power Factor

This subject was covered by a symposium at the Niagara Falls Regional Meeting of the Northeastern District, May 1926. Additional matter is submitted in the following report by H. Koenig, subcommittee chairman.

In May 1926, a symposium on dielectric loss and power-factor measurements was held at Niagara Falls. The symposium was called for the purpose of recording the then well-known methods of taking such measurements, probably as the first step toward standardizing such tests.

It is a difficult matter, of course, to determine just how effective this work was. It was the feeling of those who presented papers describing the various methods of making dielectric loss and power factor measurements that there was little hope of standardizing on any one method. The symposium did serve, however, to clear the atmosphere about these measurements and to point out the advantages and disadvantages of each method. It was also indicated at that time that a scheme for calibrating and checking the various methods now in use would be of great advantage.

Since the symposium, there have been two known advances in the line of checking dielectric loss equipments, particularly in the tests of underground cable. The first is the calorimeter method which was brought out in the discussion at the symposium by E. S. Lee of the General Electric Company. The second is the use of standard loads which have been developed at the Electrical Testing Laboratories. To the best of the Committee's present knowledge, the only checking by the calorimeter method has been done by the General Electric Company in their own laboratories. A paper entitled *A Thermal Method of Standardizing Dielectric Power Loss Measuring Equipment*, by Messrs. J. A. Scott, H. W. Bousman, and R. R. Benedict, was presented at the Baltimore Regional Meeting of the Middle Atlantic District, April 1928, describing further comparisons using this method.

During the spring of last year, a set of standard loads developed at the Electrical Testing Laboratories was used in an intercheck covering ten cable factories in the eastern part of the country. The result of this intercomparison was very satisfactory and it is hoped that some time in the near future a paper covering the tests will be written.

All other developments have been along the line of improving the technique of making measurements rather than the introduction of new circuits or methods. Neither has there been any further effort along the lines of standardizing on the method of testing.

Numerous articles have been published in some of the foreign technical magazines covering dielectric loss and power-factor measurements. No new methods have been suggested nor have radical changes been made in the methods in use in this country.

The importance of proper shielding in making dielectric power loss measurements is becoming more generally realized. A paper presented by C. L. Kasson[1] at the Pittsfield Regional Meeting May 1927, emphasized the necessity of proper shielding. The subcommittee is planning to hold a symposium on this subject in the spring of 1929 dealing with the general subject of shielding both in dielectric power loss and other measurements.

Non-Electrical Quantities by Electrical Means

This subject was reported in a paper by P. A. Borden[2] together with an accompanying bibliography. The compilation of the bibliography has been continued by Mr. Borden, a second supplement having been

*COMMITTEE ON INSTRUMENTS AND MEASUREMENTS:

Everett S. Lee, Chairman.

O. J. Bliss,	F. C. Holtz,	Wm. J. Mowbray,
P. A. Borden,	I. F. Kinnard,	T. E. Penard,
W. M. Bradshaw,	A. E. Knowlton,	R. T. Pierce,
H. B. Brooks,	H. C. Koenig,	E. J. Rutan,
A. L. Cook,	W. B. Kouwenhoven,	G. A. Sawin,
Melville Eastham,	E. S. Lee,	R. W. Sorensen,
W. N. Goodwin, Jr.,	E. B. Merriam,	H. M. Turner.

Presented at the Summer Convention of the A. I. E. E., Denver, Colo., June 25-29, 1928. Complete copies upon request.

1. *High-Voltage Measurements on Cables and Insulators*, A. I. E. E. Trans., Vol. XLVI, 1927, p. 635.
2. A. I. E. E. Trans., Vol. XLIV, 1925, p. 238.

published with the report of the Committee on Instruments and Measurements for 1926-27. A third supplement of the bibliography is included in the full report.

A study of the range of subjects in this bibliography shows the ever-increasing extension of the measurement of non-electrical quantities by electrical means. The number of the articles being published at present on this subject are too extensive for Mr. Borden to continue their compilation. Instead, a series of papers or lectures on the various subjects involved will be presented before the Institute. The lecture by Dr. C. A. Heiland on "Geophysical Methods of Prospecting" given at the Summer Convention, Denver, 1928, is the first of this series.

High-Frequency Measurements

This subject was thoroughly treated in a symposium at the Pittsfield Regional Meeting of the Northeastern District, May 1927, a résumé of which was given in the report of the Committee on Instruments and Measurements for 1926-27. Due to the wide interest in this subject and the rapid change in technique it was thought desirable to have a member act as liaison officer with the I. R. E. Committee on the Determination of Circuit Constants. The I. R. E. Committee has prepared a list of references containing the various types of measurement and in addition has developed new methods particularly with reference to the measurement of inductance of several hundred henries such as found in audio frequency transformers and choke coils both with and without superposed direct current. The report of this work is to be published. Professor H. M. Turner, subcommittee chairman, has been active in this work.

Remote Metering

The following report prepared by E. J. Rutan, subcommittee chairman, gives the results of answers to questionnaires relative to the present status of this subject.

The Instrument and Measurements Committee sent out questionnaires for the purpose of obtaining information on remote metering equipment now in use. These questionnaires were sent to a number of representative electric power companies, railroads, manufacturers, and public utility holding companies located both in this country and in Canada. From a total of 108 inquiries, 76 replies have been received as listed in Table I:

TABLE I

Group	Classification	Number of Replies
A	Electrical Transmission of Electrical Measurements	31
B	Electrical Transmission of Mechanical Measurements	10
C	Remote Metering Equipment in Use, no Data Given	3
D	Prospective Users of Remote Metering Equipment	6
E	No Remote Metering Equipment in Use	26
	Total	76

The purely electrical remote metering systems, as reported in the replies in group "A," can be classified into the ten distinct systems given in Table II.

TABLE II

Classification of Remote Metering Systems

1.	Voltage	6.	Potentiometer
2.	Impulse	7.	Frequency
3.	Position (induction)	8.	Impulse Condenser
4.	Inverse Current	9.	Contact Integration
5.	Current	10.	Thermal Converter

Referring to a paper on the *Automatic Transmission of Power Readings*, by B. H. Smith and R. T. Pierce, presented at the Midwinter Convention in Philadelphia, February 1924, it will be noted that the first seven types of systems listed in Table II were described in that paper. In the discussion that followed, the thermal converter type was also mentioned. The two systems not mentioned in the paper are not necessarily new. The contact integration system was mentioned in five replies and the impulse condenser was mentioned in two replies. Judging from the replies to the questionnaires, no new fundamental remote metering devices or systems have been developed since the presentation of the paper by Messrs. Smith and Pierce. The systems described in that paper will be given only a brief general description here but the other three systems will be described more in detail.

An attempt has been made to give an idea of the characteristics of operation and the accuracy of each method as it was reported. This was done in spite of the fact that nearly all of the users of remote metering equipment were compelled to report the performance of their systems under widely varying conditions. Certain systems whose inherent characteristics render them inaccurate due to interference from outside sources, can be made more reliable by the proper installation and shielding of the transmission line. It may also be noted that while the transmitter is often sufficiently accurate the receiver chosen to operate with it necessarily limits the accuracy of the system. This may cause the reported accuracy to be low, while a more accurate receiver would result in a more favorable reply. The importance of this point is evident when it is realized that many systems are classified according to the type of transmitter used without reference to the type of receiver. It is evident, then, that more definite information is needed to reconcile many of the apparently contradictory replies.

No attempt has been made to summarize the first cost and maintenance as no definite figures were given, and the replies received were evidently based upon the correspondent's limited knowledge of only a few of the systems in use.

1. Voltage. In this system the voltage supplied to

the receiver is varied by a potentiometer which is operated by an instrument measuring the quantity desired. Some types are varied by a Kelvin balance or relay type graphic meter. The indications are transmitted over supervising wires, pilot wires, or pressure wires, to a voltmeter type indicating, or graphic, meter.

The chief advantage of this system is its simplicity. Obvious disadvantages are its sensitiveness to changes in line resistance and the necessity for close regulation of the supply voltage.

A few companies reported the reading of voltage directly over distances from a few hundred feet to two miles.

2. Impulse. This method seems limited to watthour type meters in which impulses proportional to the speed of the meter are sent out to receivers where polarized relays actuate an escapement. Dials geared to the escapement record, the power being measured.

This method has the advantage of being positive in its action and quite independent of line conditions. The distance over which this system may be used seems to have no definite limit, the greatest reported distance being 200 miles. The receiver is a modified d-c. graphic milliammeter with a damping device to absorb the impulses. The reported accuracy seems to range from "fair" to plus or minus 1 per cent of full scale deflection.

3. Position. This method employs two similar a-c. induction motor units in which the rotor of the receiver closely follows the movements of the rotor of the transmitter.

This system is very simple and requires little or no attention. It is also very reliable, positive in action, and comparatively independent of line conditions. The line resistance limits the distance over which operation is possible, the limiting resistance being about 3000 ohms.

This method has the disadvantage of requiring five wires for operation. It is also reported that the transmitter needs a powerful operating torque, thus making it necessary to use more powerful instruments. It is sometimes necessary where a number of large receivers is connected together, to make use of power amplifying relays and motors.

The reported accuracy of this system as given by one manufacturer is 2 per cent of full scale deflection.

4. Inverse Current. This method makes use of a motor operated rheostat, controlled by the indicating or recording meter, which simultaneously adjusts the circuit resistance and the counter torque on the instrument. The receiver is a recording or indicating ammeter which receives current inversely proportional to the load.

An outstanding advantage of this method is the ease with which any number of indications may be totalized by connecting the rheostats of each meter in series. The resultant current is then inversely proportional to the total load.

The chief disadvantage lies in the complicated design and wiring necessary. The precision is also reported as being low, or only fair.

5. Current Balance. This method is similar to the inverse current method except that the rheostat is connected to a Kelvin balance type of meter and the resultant current is directly proportional to the load. The receiver may be an inverted transmitter or an indicating or recording ammeter.

These instruments may be placed in parallel and the totalized current is then proportional to the total load. This method seems quite widely used, 9 replies reporting satisfactory operation of this system. One manufacturer reported 31 users of this system, five of whom replied to the questionnaire. Seven users of method reported transmission distances of at least 3 mi. and up to 24 mi.

The accuracy appears to be good, some stating that it depends on the choice of a receiver.

6. Potentiometer. The potentiometer type may also consist of a Kelvin balance type meter which controls a motor operated rheostat, but in this case it is the line voltage which is varied. The receiver may consist of motor operated rheostat controlled by a contact making voltmeter; or as reported in one letter, a milliammeter s used.

One of the advantages of this system is that the calibration is not materially affected by a change of line resistance. Another advantage is that a telephone line may be used for transmission. This method was reported in use on lines up to 56 mi. in length. The accuracy is reported as "fair" and probably depends on the choice of equipment.

7. Frequency. This is a complex system in which a Kelvin balance type of meter is made to control the frequency of a small a-c. generator. At the receiving end a frequency meter is used, calibrated to read load power. This system is easily adapted to totalize any number of readings. The control of apparatus may also be effected.

This system does not seem suitable for customer installation due to its complex nature, involving as it does elaborate apparatus and requiring constant attention. When used by a company that uses and distributes large blocks of power over considerable distances, the excellent results that are obtained would seem to warrant its installation.

8. Impulse Condenser. In this novel system, contacts on several meters are momentarily made to connect a condenser to a charging circuit, and the receiving instruments perform a measurement upon the rate of discharge of this condenser through a resistance. This system was used over lines 3½ mi. long.

The accuracy of this system seems to be low. The information received for this method is meager, but little seems to be said in its favor.

9. Contact Integration. This system may consist of contacts operated by a watthour meter, wherein the

total number of contacts made over the system is totalized on a recording instrument, or the contacts made by demand meters are recorded at one point on one instrument. The greatest reported distance of transmission was 5 mi., but this range may be extended by the use of suitable relays.

The accuracy of this method seems to depend upon the type of transmitters and receivers and the amount of local interference. Accuracies from one to two and one-half per cent were reported.

This system apparently gave satisfactory service in four out of five reported cases, while the fifth correspondent reported a failure due to induction from a nearby high-voltage line.

10. Thermal Converter. The important unit in this system is known as a thermal converter; and consists of two heating elements so connected to the instrument current and potential transformers that the temperature difference of the two elements is proportional to the watts in the metered circuit. Thermocouples are placed in this converter in such a manner that the "hot" junctions are associated with one heating element and the cold junctions with the other. The resultant thermoelectric potential is proportional to the difference in temperature of the two heating elements and is therefore proportional to the watts or power in the circuit. It was found possible to design the thermal converters to give a linear characteristic over the range used, and thus allow the units to be connected in series, when it is desired to totalize loads from a number of sources.

The accuracy of this method seems to lie in the receiver, which is usually a high-grade recording potentiometer, when accuracy may be of the order of one-half of one per cent. Thus, a null method of measurement is used practically eliminating any possible effect due to changes in line resistance. Indications have been transmitted successfully up to 8 mi. over telephone and supervisory lines. Other reported advantages are the lack of moving parts in the transmitting unit and the complete reversibility of the converters. This latter feature permits the use of this method on tie feeders where a reverse of power may occur.

This is the only new type of system developed since 1922 which has come to the attention of the committee. Arrangements are being made for the presentation of a description of this system before the Institute.

Conclusion

It is still the feeling of the subcommittee that sufficient operational data have not yet been submitted to allow conclusions to be drawn as to the accuracy of the remote metering systems in use.

Additional Subjects

In addition to the work being carried on by the standing subcommittees as reported above, there are several other subjects which the committee are working upon as the following:

System Disturbances

There is a growing demand for recording instruments for switchboard application to record the variation of current, voltage, and power with time during system disturbances. In this connection, a symposium was held jointly by the Committee on Protective Devices and the Committee on Instruments and Measurements at the New Haven Regional Meeting, May 1928, at which time two series of papers were presented, one describing available instruments for making these measurements and the other giving the experiences of the operators in the use of these instruments. This symposium was under the direction of R. T. Pierce for the Committee on Instruments and Measurements. The papers presented under the auspices of this committee were:

Hall High-Speed Recorder, by C. I. Hall

Pages from the Hall High-Speed Recorder, by E. M. Tingley

Oscillograph Recording of Transmission Line Disturbances, by J. W. Legg

High-Speed Graphic Voltmeter, by A. F. Hamdi and H. D. Braley.

Revision of Electrical Units

Following the presentation of Dr. E. C. Crittenden at the Summer Convention of the Institute, Detroit, 1927, of a paper entitled *The International Electrical Units*, a resolution was presented and passed that the matter of the revision of the electrical units should be referred to the Committee on Instruments and Measurements for their consideration and study. This has been done and resolutions have been prepared and transmitted to the Board of Directors through the Standards Committee, urging the United States Bureau of Standards and other foreign national standardizing laboratories to undertake the necessary researches to eliminate the present discrepancies between the legally established electrical units and the absolute units which they were intended to represent, and to urge the legalization of absolute units.

Measurement of Core Losses in Terms of Sine-Wave Core Losses

The Committee on Instruments and Measurements has been asked to investigate and report on the best way to make core loss measurements so that they will give accurate sine-wave core losses regardless of the wave form employed for excitation. This subject is being studied by a working committee under the chairmanship of W. M. Bradshaw.

Distortion Factor—Definition and Method of Measurement

The Committee on Instruments and Measurements has been asked to give consideration to the adoption of a definition for distortion factor and methods of

test, as disclosed in a report of the French Electrotechnical Commission entitled "Methods of Determining the Distortion of the Voltage Wave of Alternators." This matter is being considered by a working committee under the chairmanship of W. M. Bradshaw

ACKNOWLEDGMENT

It is but fitting that we recall at this time the contribution in the past to the work and activities of this committee by J. R. Craighead. Mr. Craighead was appointed Chairman of the Instruments and Measurements Committee at the beginning of this year but he was removed from us by sudden death November 22, 1927. In his passing there have been lost to us the contributions of an active and energetic worker, and the advice and counsel of a scholar.

EVERETT S. LEE, *Chairman.*

Abridgment of

Squirrel-Cage Rotors With Split Resistance Rings

BY HANS WEICHSEL[1]

Fellow, A. I. E. E.

Synopsis.—*The characteristics of a squirrel-cage induction motor are investigated when the resistance rings are provided with cuts 360 electrical degrees apart and the cuts in the front ring are displaced against those in the back ring by 180 electrical degrees.*

There is given a theoretical investigation which leads to the conclusion that splitting the rings results in an equivalent ring resistance which varies with double-slip frequency in the ratio of one to three; and the average ring resistance is twice what it was before the rings were cut. The variable rotor resistance effects a periodic fluctuation of the line current and rotor speed. The fluctuations have double-slip frequency. The theoretical conclusions are checked by tests and oscillograms. Test results show that the splitting of the rings is followed by increased rotor leakage, which results in a starting torque smaller than that corresponding to the increased resistance and original leakage.

* * * * *

WHEN the starting torque of a squirrel-cage induction motor is not sufficiently high, the remedy often suggested is to divide each resistance ring into half as many sections as there are poles, the cuts in the front ring being displaced by 180 electrical degrees, against those in the back ring as shown in Fig. 1.[2]

Such a squirrel-cage rotor offers a resistance higher than an identical squirrel-cage with uncut rings. Below, it will be determined how much that part of the squirrel-cage rotor resistance, which is due to the rings only, is increased by the cutting. It will be found that a squirrel-cage with cut rings offers an *average* ring resistance equal to twice the resistance of the original uncut rings. The proof follows:

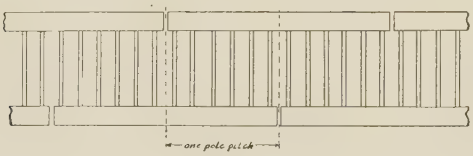

FIG. 1

Fig. 4 approximates the current distribution in a two-pole squirrel-cage rotor with solid rings.

The rotor bar ampere-conductor distribution rotates in respect to a fixed point on the rotor with a speed corresponding to slip frequency. The shape of the distribution remains unaltered.

If the distance between two adjacent rotor bars is δ electrical degrees, and the rotor has an even number of bars per pole, the current in the different bars has the following values:

$$\text{Current in bar } I_1 = I \times \text{sine} \frac{\delta}{2}$$

$$\text{Current in bar } I_2 = I \times \text{sine}\, \delta + \frac{\delta}{2}; \text{ etc.}$$

These equations are vectorially represented in Fig. 3. The vectors 1-2, 2-3, 3-4, 4-5 are alike and equal to I (*i. e.*, the maximum bar current), and are displaced against each other by the angle δ. These vectors form a polygon, the circumference of which approaches $2\,Z \times I$, where Z is the number of squirrel-cage bars for one pole. The radius of a circle circumscribing this polygon is given by:

$$r = \frac{2\,Z\,\bar{I}}{2\,\pi} = \frac{Z\,\bar{I}}{\pi} \qquad (1)$$

In Fig. 3 the bar currents are represented by the lines 2-7, 3-8, 4-9, etc. and are equal to the projection of the lines 1-2, 2-3, 3-4, 4-5, etc. on the horizontal diameter 0-1.

From Fig. 4 the distribution of currents in the ring can be derived. The section A of the ring does not

1. Consulting Engineer, Wagner Electric Corporation, St. Louis, Mo.

2. This scheme was originally suggested by Zieglke, see Electric Motors, by H. M. Hobart, p. 314.

Presented at the A. I. E. E., Regional Meeting., St. Louis, Mo., March 7-9, 1928. Complete copies upon request.

carry any currents at all; section B carries current I–3; and section C carries the current I–3 plus I–2, etc. Therefore, the ring current is a maximum where the bar current is zero, and the ring current is zero where the bar current is a maximum.

By applying this to Fig. 3, it follows that the current in ring section C can be expressed as:

$$I_c = r \cos (90 - \gamma) = r \sin \gamma \qquad (2)$$

where γ is the distance, measured in electrical degrees, from the center of section C to the center of section A.

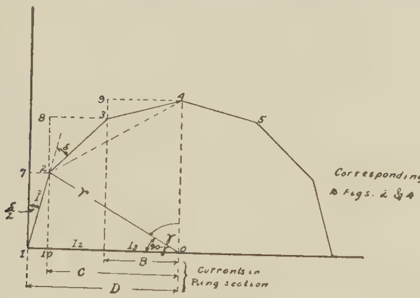

Fig. 3

Equation (2) demonstrates that the current distribution in the rings follows a sine curve, being zero at the point A. As seen previously, the current distribution in the bars follows a sine curve, being zero at the point D. Points D and A are 90 deg. displaced from each other. Therefore, if both curves refer to the same starting point, one of the curves is a sine curve and the other is a cosine curve. From equation (1) and (2), it follows that

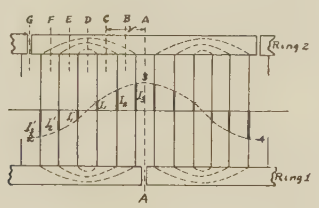

Fig. 4

the ring current at any section γ, as a function of the maximum bar current $\bar{I}$, is:

$$I_\gamma = \frac{Z \bar{I}}{\pi} \sin \gamma \qquad (3)$$

The loss in the ring is at any point proportional to the square of the current and is, therefore:

$$\frac{Z^2 \bar{I}^2}{\pi^2} \sin^2 \gamma \times \frac{R}{2\pi} \qquad (4)$$

The total loss per ring per pole, is the integral of Equation (4), which is: $\dfrac{R Z^2 I^2}{4 \pi^2}$

Consequently the losses in both rings per pole pair equal:

$$\frac{2 R Z^2 \hat{I}^2}{\pi^2} \qquad (9)$$

Where R = resistance of ring spanning two-pole pitches
Z = number of squirrel-cage conductors per pole
$\hat{I}$ = effective rotor-bar current per pole = $I \sqrt{2}$.

Figs. 4 and 6 show a two-pole squirrel-cage winding with end rings split in the manner described, under the assumption that the current distribution in the squirrel-cage bars follows a sine law.

Curve 2–3–4 (Fig. 4) represents the moment the maximum bar current coincides with the slot A in the ring No. 1.

The ring currents in Fig. 4 plotted in a coordinate system as a function of space gives Fig. 5.

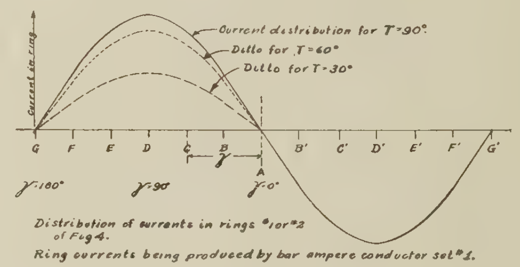

Fig. 5

Conditions change materially for the moment when the bar carrying no current coincides with the cut A in ring No. 1, as shown in Fig. 6. The only symmetrical

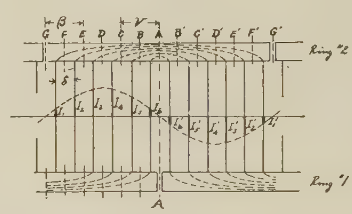

Fig. 6

ring distribution possible with the symmetrical bar distribution is that given in Fig. 6, *i. e.*, section F in ring 2 must carry the bar current I_1. The section E carries bar current I_2 plus I_1, etc. Finally, section A carries the sum of all bar currents of one pole, *i. e.*, $I_1 + I_2 + I_3 + I_4 + I_5 + I_6$.

From this follows Fig. 7, where vectors 1–2, 2–3, etc. represent the maximum current in any of the rotor bars. Each vector forms with its preceding vector an angle δ equal to the displacement of the bars against each other. The current I_1 in bar No. 1 is given by the distance 2–7, and the current I_2 in bar 2 is given by the vector 3–8, etc., which are equal to the projections of the vectors 1–2, 2–3, etc. on the base line 0–1′. The current passing through the ring section F is equal to the bar current I_2. Consequently. it is given by the length 2–7 or 1–10 (Fig. 7). The current through the ring section E is the sum of bar current I_1 and I_2. Consequently it is given by the length 1–11, which is the projection of the vectors 1–2 and 2–3.

The currents in the different sections, A, B, C, D, E, and F, plotted as function of their space location, give a current distribution in the ring as shown in Fig. 8.

In Fig. 6 the center of the ring section E is β electrical degrees displaced against the point G. Consequently, in this case $\beta = 2\,\delta$. The ring point D is displaced by an angle $\beta = 3\,\delta$, etc. In Fig. 7, the angle β of Fig. 6 appears as angle 1–0–3, if the ring section E is under

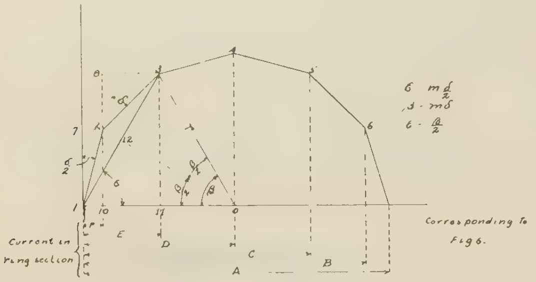

FIG. 7

consideration; or an angle 1–0–4 if point D is under consideration, etc. From triangle 1–0–3, it follows that the ring current in section E, which is the projection of the vector 1–3 on the base line, is given by:

$$I_\beta = 2\,r \sin \frac{\beta}{2} \;.\; \cos \epsilon \tag{11}$$

but from the triangle 1–0–12, it follows that:

$$I_\beta = r\,(1 - \cos \beta) = \frac{Z\,\bar{I}}{\pi}\; 1 - \cos \beta) \tag{16}$$

This equation gives the ring current in a split ring as function of the angle β (Fig. 6), which, when plotted in

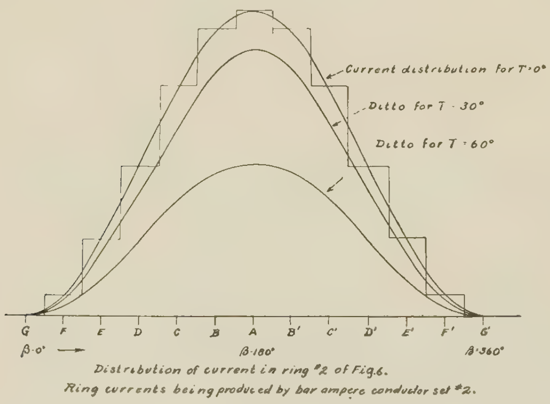

FIG. 8

coordinate system, gives the curve of Fig. 8. The loss at any point of the ring is obtained by squaring equation (16) and multiplying it with the coefficient $\dfrac{R}{2\,\pi}$.

The loss at any point of the ring is, therefore:

$$I_\beta^2\,k = r^2\,(1 - \cos \beta)^2\,\frac{R}{2\,\pi} \tag{17}$$

The total loss per ring is the integral of this equation taken between the limits of 0 to 360 deg., which gives:

$$r = \frac{Z\,\bar{I}}{\pi}$$

The losses for both rings per pole pair equal:

$$\frac{3\,R\,Z^2\,\bar{I}^2}{\pi^2} = \frac{3\,R\,Z^2\,\bar{I}^2\;.\;2}{\pi^2} \tag{20}$$

This equation compared with (8) shows that the ring loss for a current distribution (Fig. 6) is three times as large as the ring loss for a current distribution (corresponding to see Figs. 4 and 5).

From the above, it follows that the *maximum ring current, for a distribution as shown in Figs. 6, 7, and 8, is the sum of all bar currents of one pole; while for the distribution shown in Figs. 3, 4, and 5, the maximum ring current is only the sum of one-half the bar currents of one pole.* The ring losses must vary with time as is shown in Figs. 4 and 5. In order to determine the actual loss in the rings, it is to be remembered that a rotating sine-shaped field can be considered as being made up of two alternating sine-shaped stationary fields, which are located at right angles to each other and with alternations of 90-deg. time displacement. Consequently, sine-shaped distributed rotating ampere conductors (bar currents are under discussion) can be considered as being made up of two sets of ampere conductors:

Set No. 1, whose axis is located as per Fig. 4, *i. e.*, the maximum of the ampere conductors coincides with the slot A in the ring.

Set No. 2, whose axis is located as per Fig. 6, *i. e.*, it is 90 electrical degrees displaced from the slot A.

For instance, for Fig. 4 the ring current distribution in space is given by Fig. 5. For the time $T = 0$, it has been assumed that the current is zero; for the time $T = 90$ deg., the current distribution has reached its maximum; and for the time $T = 30$ and $T = 60$, the distributions lie between the two mentioned extremes.

For the ampere conductors set No. 2 of Fig. 6, the ring current distribution varies with time as per Fig. 8, which shows this distribution for the time $T = 0$, $T = 30$, and $T = 60$ deg. For the time $T = 90$ deg., the current distribution is zero and is equivalent to the base-line of Fig. 8. For reasons of symmetry, the current distributions in rings No. 1 and No. 2 must have the same general shape. However, the current distribution in ring No. 1 must be displaced 180 electrical degrees against the current distribution in ring No. 2, since it is seen that the current in ring No. 1 is zero at point A and the current in ring No. 2 is a maximum at point A. The distributions of rings No. 1 and No. 2 for a given time instant are given in Fig. 9.

In reality, the ring distributions as shown in Figs. 4 and 6 occur simultaneously. Consequently, the resultant current distributions in each ring must be the sum of the currents from Figs. 5 and 9.

Fig. 10 shows the current distribution of ring No. 2

for the time $T = 45$ deg. For a different time instant, the resultant ring distribution has a different shape. For $T = 0$ the resultant distribution in ring No. 2 is as shown in Fig. 8. For $T = 90$ the resultant distribution in ring No. 2 is as shown in Fig. 5.

It must be clearly understood that for any other time instant than that illustrated in Fig. 10, the magnitude of the ordinates of curves I and II changes, while the

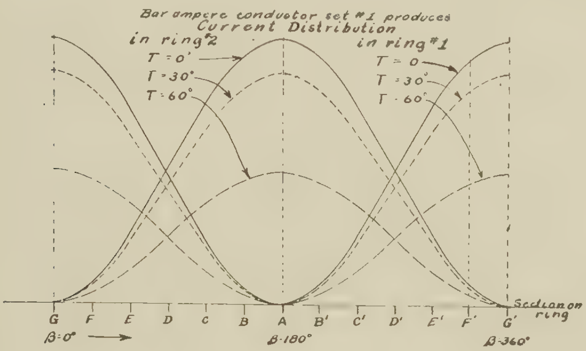

Fig. 9

relative shape of curves I and II does not alter. On the other hand, the shape and the magnitude of curve III alters with time. At any instant, the resultant current flow in any ring section,—say, for instance, section C,—consists of a current due to the current corresponding to curve I, (*i. e.*, equal to a), and a current due to curve II, (*i. e.*, equal to b). The total instantaneous current in ring

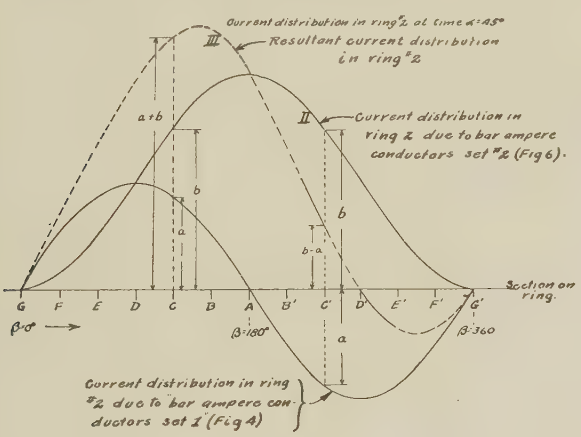

Fig. 10

section C is, therefore, $a + b$. The instantaneous loss in the ring section C is proportional to the square of the resultant current, and hence is proportional to $(a + b)^2$, the instantaneous current in section C' is $b - a$, and the loss in this section is proportional to $(b - a)^2$. Consequently the combined loss in sections C and C' is the sum of the losses in C and C' and is given by:

$$2\,(a^2 + b^2) \tag{21}$$

This equation demonstrates that *the sum of the instantaneous losses in any two symmetrically located ring sections equals the sum of the losses produced independently in each section by the ring currents a and b.* Consequently, the total losses in ring No. 2, at any moment is equal to the sum of the instantaneous ring losses due to currents I and II which leads to a total ring loss according to the equation:

$$L = 1 + 2\cos^2\alpha \tag{25}$$

The results of equation (**25**) are graphically represented in Fig. 12. It will be seen that the resultant loss in

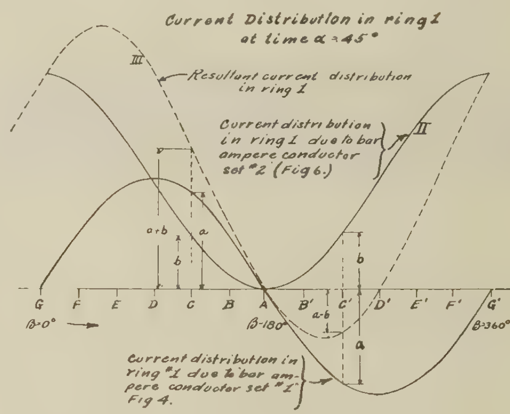

Fig. 11

ring No. 2 fluctuates between the extremes of $3 \times \bar{L}_1$ and $\bar{L}_1$. The time intervals between two successive maxima correspond to one-half slip periodicity.

So far, the losses were derived for the current distributions existing in ring No. 2. It was shown that the current distribution in ring No. 1, due to bar ampere conductor set No. 2, is the same as in ring No. 2, but is 180 deg. displaced in space against the distribution in ring No. 2, as shown in Fig. 9.

The ring current distribution in rings Nos. 1 and 2, due to the bar ampere conductor set No. 1, are, however,

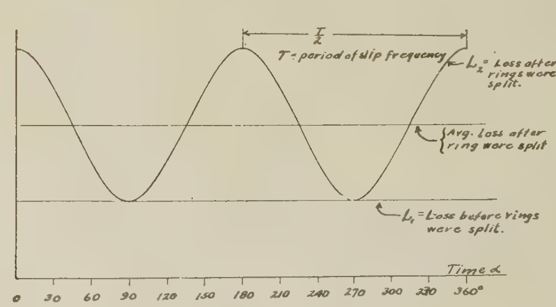

Fig. 12

identical in every respect. Consequently the resultant current distribution in ring No. 1 is as shown by curve 3 in Fig. 11, which is identical to Fig. 10 with the exception of curve 3 being shifted 180 deg. in space against curve 3 of Fig. 10.

The resultant losses in ring No. 1 must vary in time in accordance with the same law as the resultant losses in ring No. 2, (see Fig. 13). The losses in rings Nos. 1 and 2, therefore, reach a maximum at the same time, and also reach a minimum at the same time. It can be stated that for a given effective bar current, the losses in

the split-rings vary in the relation of 3 to 1 and have maximum at time intervals equal to one-half slip periodicity. In order words, the ring losses fluctuate in time with double-slip frequency, (see Fig. 14).

From equation 25 it follows that the average loss is given by:

$$(L_1 + L_2) \text{ avg.} = 2\,\overline{L}_1 \quad \textbf{(26)}$$

which means that the *average* ring loss in a squirrel-cage with split-rings is two times as large as the losses in an

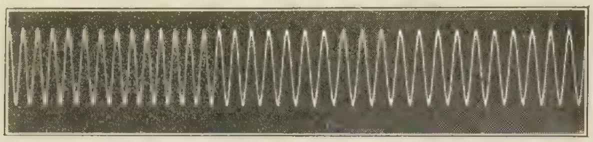

Fig. 13

unsplit ring, as long as the effective currents in the bars are kept constant, which is equivalent to saying: *The ring resistance of a squirrel-cage with split rings varies in the ratio of 3 to 1 with a frequency of two times slip frequency. The average ring resistance is equal to two times the resistance of an unsplit ring.*

Consequently with *absolutely constant rotor speed,* the effective value of the bar currents fluctuates with double-slip frequency, which in turn means that the rotor torque fluctuates with double-slip frequency. Such a condition exists when the inertia of the rotor and the driven machinery is very large. When the rotor

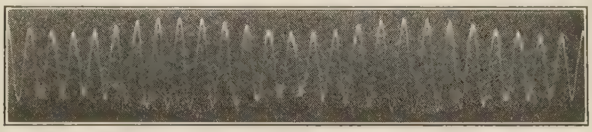

Fig. 14

and the driven machine have infinitely small inertia and the mechanical load torque is held constant, the slip of the machine must vary periodically and the rotor bar currents remain constant in order to produce constant torque.

In practise, the conditions lie between the two extremes just discussed; that is, the speed and the current change. As a rule these changes will not be found very objectionable.

The higher the average slip, the faster are the torque impulses, and the greater is the tendency for the machine to run at constant speed.

An oscillogram of the full-load line current taken on a 7½-hp., four-pole, 60-cycle, two-phase, 220-volt squirrel-cage motor with split rings is shown in Fig. 14. The fluctuation in the magnitude of the line current is clearly shown in this oscillogram. Fig. 13 shows the line current on the same machine, but provided with a squirrel-cage without split rings. No fluctuations whatsoever are noticeable in this case in the magnitude of the line current.

A brief outline of the test results obtained on such a machine is,

1. The time interval between two current maximums equals 2.06 times the measured slip frequency as compared with the theoretical value of 2.

2. A plot ofthe kilowatt input per phase and various angular positions of the rotors showed that the one with cut rings had an equivalent rotor resistance of 2.82 times the resistance of the same rotor with uncut rings as compared with the theoretical value of 3, which considers the ring resistance only.

3. The leakage of a tested machine with cut rings was found to be 1.27 times that of the same motor with uncut rings and, therefore, the actual gain in resistance is offset by this increase in leakage, and tests in this case showed a decrease in starting torque.

4. The beneficial effect of splitting rings as found by this test is in the torque per ampere. With split rings, the torque per ampere was increased from 1.16 to 1.35.

5. The maximum horsepower of the tested machine is decreased to 78 per cent of the original with uncut rings by splitting them in the manner described above.

RADIO BEACONS

The radio beacon will inaugurate an epoch of safe and regular flying, a research narrative prepared for the Engineering Foundation by the U. S. Bureau of Standards, Department of Commerce, declares.

"It is impossible," the Bureau points out, "to exaggerate the solitude and helplessness of an airplane flying in the dense fog. Deprived of all landmarks, under incessant strain to maintain equilibrium and direction, the aviator must abandon dependence upon his senses and navigate by his instruments. It is contrary to human instinct to throw overboard the testimony of the senses and stake life on an instrument. Not every pilot can do it.

"One instrument tells the pilot his elevation, another whether he is turning or flying straight away, and his compass indicates his general direction. They do not tell him if he is drifting sidewise due to a cross wind, nor at what speed he is traveling because the wind may slow him down or speed him up. What 'instrument flying' has lacked is supplied by the radio beacon.

"Successful flights have been made up to 135 miles, in fog and over hazardous mountain terrain. This distance is more than enough to demonstrate the success of the system, as it is contemplated that beacon stations will be placed not over 200 miles apart, with a straight airway between them. They will be supplemented by small marker beacons at intervals. A characteristic signal from a marker beacon will show on the visual indicator aboard the airplane what point is being flown over.

"With the beacon stations in operation throughout the country, airplanes in flight will always have the beacon signals available to keep them constantly informed of their locations. Indeed, when a pilot leaves his regular course either accidentally or to avoid a stormy area, the radio shows him the way back."

Institute and Related Activities

Pacific Coast Convention, August 28-31, 1928 Has Diversified Program

A varied and comprehensive program is arranged for the Pacific Coast Convention of the Institute, which will be held August 28-31, with headquarters in the Davenport Hotel, Spokane, Wash. The technical sessions, inspection trips and social events all promise to be excellent.

Technical Features

In the technical sessions a great diversity of live topics will be covered including movements of overhead conductors, choice of transmission voltages and wire sizes, transmission diagrams, system stability, residual voltages, lightning and lightning arresters, power-line carrier communication, automatic substations, heat flow from cables, cable-sheath corrosion, sphere and point-gap calibration, gaseous-conductor lamps, railway electrification, mercury-arc rectifiers automatic railway signals, and electrolytic zinc refining.

A feature will be a lecture on *Lichtenberg Figures* by Dean C. E. Magnusson, University of Washington, on the evening of Wednesday, August 29. A film describing transatlantic telephone service will be shown on Friday evening.

It is planned also to have two Student sessions held on the mornings of August 28 and 30. At these sessions members of A. I. E. E. Student Branches will present and discuss papers. All institute members are invited to attend. A conference on student activities will be held on the evening of August 31 by Branch counselors and students of Districts 8 and 9.

Inspection Trips

A number of attractive inspection trips have been planned. These trips will be taken at times convenient to the visitors. A trip may be made to the Coeur d'Alene district to see the new electrolytic zinc smelter of The Sullivan Mining Company and the Coeur d'Alene mines. This trip is very attractive also from the scenic and historic standpoints.

The Chelan hydroelectric station of The Washington Water Power Company, the Great Northern Railway electrification through the Cascade Mountains, and the outdoor hydroelectric station of the Pacific Power & Light Company at Lewiston, Idaho are new points of interest which may be visited.

In addition there are the Long Lake Station and other stations of The Washington Water Power Company, the alternating-current underground system in Spokane and the Milwaukee Railway electrification.

Entertainment

Among the recreational events which have been planned are a reception and dance on the evening of Tuesday, August 28, and a banquet with entertainment on Thursday evening. A golf tournament will be played for the John B. Fisken cup.

The ladies who attend the convention are invited to all affairs and special entertainment has been arranged particularly for them. This includes drives, teas, card parties and golf.

Hotel Reservations

Each member who wishes hotel accommodations should request them directly from the hotel management. Rates are given below for the Davenport Hotel, which will be convention headquarters, and for other hotels within easy walking distance.

HOTEL ROOM RATES PER DAY

Hotel	Single room: Without bath	Single room: With bath	Double room: Without bath	Double room: With bath
Davenport	$2.25-2.50	$3.00-6.00	$3.50-4.00	$4.50-10.00
Spokane, Coeur d'Alene, Dessert	$1.50 up	$2.00 up	$2.50 up	$3.50 up

Railroad Rates

Regular summer excursion rates are available for travel to Spokane. Members should consult their local ticket agents about these and other possible reduced rates.

Registration

All who plan to attend are requested to notify the chairman of the Registration Committee, as this will be helpful in making plans. This chairman is James B. Fisken, of the Washington Water Power Company, Spokane, Wash.

Committees

The General Committee which is managing local arrangements consists of: John B. Fisken, Chairman; M. W. Birkett, D. L. Brundige, H. P. Charlesworth, D. L. Huntington, W. S. McCrea, Jr., E. R. Northmore, G. E. Quinan, L. C. Williams, W. L. Winter, J. E. Yates, A. C. R. Yuill, and the following chairmen of subcommittees as indicated: *Program,* L. R. Gamble; *Entertainment,* G. S. Covey; *Hotels,* E. R. Hannibal; *Transportation,* D. F. Henderson; *Publicity,* Richard McKay; *Finance,* Bernhard Olsen; *Registration,* James B. Fisken; *Golf,* J. E. E. Royer; *Local Trips,* Joseph Wimmer; *Ladies Entertainment,* Mrs. L. R. Gamble.

PROGRAM FOR PACIFIC COAST CONVENTION

(All meetings held in Davenport Hotel)

TUESDAY, AUGUST 28

9:00 a. m. Registration.

10:00 a. m. Student Technical Session.

The Phenomena of the Synchronous Breakdown of the Fynn-Weichsel Motor, N. C. Clark, University of California.

The Fynn-Weichsel Motor as a Generator, O. K. Stigers, University of Utah.

The Fynn-Weichsel Motor as A Self-Excited A-C. Generator, Herman Reise, University of Washington.

Electrical Characteristics of Neon-Gas Tubes, G. R. Crane and E. W. Templin, California Institute of Technology.

Voltage-Ratio Characteristics of Audio-Frequency Transformers Determined by the Cathode-Ray Oscillograph, P. J. Klev, Jr. and D. W. Shirley, Jr., Oregon State College.

2:00 p. m. Technical Session.

Tests on Sphere-Gaps and Point-Gaps up to 2,100,000 Volts, J. S. Carroll and Bradley Cozzens, Stanford University.

High-Voltage Gaseous-Conductor Lamps, F. O. McMillan and E. C. Starr, Oregon State Agricultural College.

The Automatic Substation and Its Relation to the Electric Distribution System, S. J. Lisberger, Pacific Gas and Electric Co.

The Design of Power Systems for Stability, R. H. Park and E. H. Bancker, General Electric Co.

8:00 p. m. Reception and Informal Dance.

WEDNESDAY, AUGUST 29

9:00 a. m. Technical Session.

The Electrolytic Zinc Plant of the Sullivan Mining Company, E. R. Fosdick, The Washington Water Power Co.

The Great Northern Railway Electrification, E. L. Moreland and R. D. Booth, Jackson & Moreland.

Power Supply for Railway Signals and Automatic Train Control, C. F. King, Westinghouse Electric & Mfg. Co.

Automatic Mercury Arc Power Rectifier Substations, L. J. Turley, Los Angeles Railway Corp.

2:00 p. m. Golf Tournament at the Spokane Country Club.

8:00 p. m. Address. *Lichtenberg Figures*, by Dean C. E. Magnusson, University of Washington.

THURSDAY, AUGUST 30

9:00 a. m. Student Technical Session.

The Effect of Barriers in Insulating Oil, Birney Dysart, Stanford University.

Temperature Rise Due to Eddy Currents in Iron, A. F. Betke and D. R. Stanfield, University of Southern California.

Power Factor and Power Rates, H. B. Tinling, State College of Washington.

The Three-Phase Induction Regulator on Unbalanced Loads, L. W. Curtis, University of Idaho.

2:00 p. m. Technical Session.

Movements of Overhead Line Conductors during Short Circuits, Wm. S. Peterson, Los Angeles, Bureau of Power and Light, and H. J. McCracken, Jr., Los Angeles Dept. of Water and Power.

Economy in the Choice of Line Voltages and Conductor Sizes for Transmission Lines, E. A. Loew, University of Washington.

Generalization of Transmission-Line Diagrams, H. V. Carpenter, Washington State College.

Residual Voltages and Currents in Power Systems, L. J. Corbett, Pacific Gas an Electric Co.

6:30 p. m. Banquet and Entertainment.

FRIDAY, AUGUST 31

9:00 a. m. Technical Session.

Power-Line Carrier Telephony, L. F. Fuller and W. A. Tolson, General Electric Co.

Problems in Power-Line Carrier Telephony, W. V. Wolfe and J. D. Sarros, Bell Telephone Laboratories.

Carrier-Telephone System for Short Toll Circuits, H. S. Black, Bell Telephone Laboratories, M. L. Almquist and L. M. Ilgenfritz, American Tel. & Tel. Co.

2:00 p. m. Technical Session.

Lightning-Arrester Problems, A. L. Atherton, Westinghouse Electric & Mfg. Co.

High-Voltage Phenomena in Thunderstorms, M. A. Lissman, Stanford University.

Heat Flow from Underground Electric Power Cables, N. P. Bailey, University of Idaho.

Cable-Sheath Corrosion in Creosoted Wood Duct, R. M. Burns, Bell Telephone Laboratories, and B. A. Freed, Pacific Tel. & Tel. Co.

8:00 p. m. Film, showing transatlantic telephone service. Conference on Student Activities Districts 8 and 9.

SATURDAY, SEPTEMBER 1

Inspection Trips.

Regional Meeting in Atlanta, October, 19-31

Plans are progressing nicely for the regional meeting in Atlanta, Ga., which will be held under the auspices of the Southern District of the Institute, October 29 to 31.

There will be four general topics covered in the technical sessions; namely, hydroelectric power development, power-system operation, communication and textile mills. In addition there will be papers and addresses on other subjects including dynamo design, radio broadcasting, photoelectric and glow-discharge devices, etc.

Further information will be given in later issues of the JOURNAL.

Opportunity to View Ordnance Tests

Members of the A. I. E. E. are invited to attend the Tenth Annual Meeting of the Army Ordnance Association to be held at the Aberdeen Proving Ground, Maryland, Thursday, October 4, 1928, with opportunity to witness one of the most instructive and spectacular military demonstrations in the world. Special arrangements have been made whereby they may attend meeting from practically any point in the United States at reduced railroad fare, using fare certificates permitting them to purchase round trip tickets at one and one-half times the one way fare.

These annual gatherings, sponsored by the A. O. A., are purely educational. With the approval of the Secretary of War and the cooperation of the various branches of the Army, guests are permitted to witness tests of modern munitions. Aberdeen Proving Ground is the great proving ground on the shores of Chesapeake Bay, and it may be said that assembled there is the most interesting collection of armament—new and old—in this country and possibly in the world. Its 35,000 acres afford ample space to actually fire the huge long range guns, test demolition bombs, tank and tractors, and airplane equipment.

The purpose of these annual gatherings is to acquaint executives and engineers of American industry with the latest developments in armament should they ever be called upon to produce them. The program, beginning at 10 a. m., lasts throughout the day and concludes in early evening with antiaircraft firings. Details have not yet been announced but there is every indication that this year's demonstrations will exceed in interest any previous ones.

The Army Ordnance Special—a train of sleeping cars—will be operated from New York, N. Y., leaving Pennsylvania Station after midnight, October 3rd, and returning by midnight October 4th. Also several of the regular trains on both the Pennsylvania and Baltimore and Ohio Railroads between New York and Washington will make special stops at Aberdeen on October 4th. Full particulars concerning the special train are obtainable from Maj. P. R. Faymonville, Secretary, New York Post, Army Ordnance Association, 810 Army Bldg., 39 Whitehall Street, New York, N. Y.

Dinner and supper will be served at the Proving Ground. Reservations should be made well in advance to the Commanding Officer, Aberdeen Proving Ground, Aberdeen, Md., who hopes that all Institute members who can will attend this premier exhibition.

Profitable and Enjoyable Summer Convention in Denver

One of the most successful of the Institute's Summer Conventions was held June 25 to 29 in Denver, Colorado, with headquarters at the Hotel Cosmopolitan. A very fine technical program and unusually attractive entertainment were offered to the 500 members and guests who attended; also a number of committee and business meetings were held.

Six technical sessions were held at which were presented 19 papers and 15 Technical Committee reports. A summarized report of these sessions and the discussion presented at them is given in subsequent paragraphs.

A most interesting lecture on *Geophysical Methods of Prospecting* by Dr. C. A. Heiland, Colorado School of Mines, was presented on the evening of June 26. In the absence of Dr. Heiland the lecture was delivered by J. H. Wilson of the Colorado School of Mines.

Annual Business Meeting

The Annual Business Meeting of the Institute was held on Tuesday, June 26. A full account of this meeting is given on page 540 of the July Journal. The report of the Tellers Committee made at this meeting is given on page 538 of the June Journal. The Institute prizes for papers were announced as reported on page 616 of this Journal. The presidential address of President Gherardi, presented at this meeting, is published on page 579 of this Journal.

Entertainment

A most hospitable and enjoyable entertainment program was carried out, including trips, social functions and sports. Probably the most remarkable event was the all-day trip on June 28 which was taken by over three hundred people in private automobiles. The round trip was over 130 miles of beautiful mountains with lunch served on the village green at Idaho Springs. A reception on the evening of June 26, a banquet and dance June 27, and a theater party June 28, were other high spots. At the banquet two lectures were given respectively by T. S. Dines, Director of the United State Chamber of Commerce, and Dr. A. B. Hulbert of Colorado College. The former spoke on the work of the Chamber of Commerce and Dr. Hulbert's subject was *The Relation of Frontiering to Civilization.*

The ladies attending were kept busy every minute enjoying the events named above and also various drives, teas, card parties and swimming.

In golf the winner of the tournament for the Mershon Trophy was W. C. Heston. The runner-up was A. C. Cornell. The order in which the contestants finished in the other golf events was as follows:

Kickers Handicap

(1) E. C. Searing, (2) Ray Gheen, (3) E. R. Northmore, (4) J. C. Yates, (5) Chas. W. Keller.

Match Play against Par

(1) F. P. Ogden, (2) A. W. Wennerstrom.

Low Gross

(1) Geo. B. Luther, (2) W. A. Schumacher, (3) A. H. Sweetnam.

High Gross

(1) A. M. Lloyd, (2) R. W. Sorensen, (3) E. B. McCabe.

In the tennis singles tournament the winner was P. H. Hatch and the runner-up, E. H. Hubert. No doubles tournament was played.

All who attended the convention were impressed with the hospitability of the local members and the very pleasing way in which all events were conducted. The Board of Directors at its meeting on June 27 adopted a resolution expressing appreciation for the highly effective services of the members of the various local committees in making and carrying out the plans. Also similar resolutions were adopted at the two parallel sessions held on June 29.

DIGEST OF TECHNICAL SESSIONS

A summarized report of the discussion at technical sessions is given in the following paragraphs. The complete discussion will be published with the corresponding papers in the Transactions.

Session on Surge-Voltage Investigations

1. *Surge-Voltage Investigation on Transmission Lines,* W. W. Lewis.
2. *Lightning Investigations on New England Power Company's System,* E. W. Dillard.
3. *Surge-Voltage Investigation on 140-kv. System of Consumers Power Co.,* J. G. Hemstreet and J. R. Eaton.
4. *Surge-Voltage Investigation on 132-kv. Transmission Lines of American Gas and Electric Co.,* Philip Sporn.
5. *Surge-Voltage Investigation on 220-kv. System of Pennsylvania Power & Light Co.,* N. N. Smeloff.

In discussing these papers J. F. Peters stated that in some voltage investigations which he had made a condenser-type bushing, with a tap taken from the next-to-bottom condenser layer, was used as a potentiometer and the results were entirely unsatisfactory due to the high capacitance of the bushing. He suggested that too high a capacitance should not be used. L. R. Ludwig, in a written discussion, stated that, although the cheapness of the insulator-string potentiometer makes it attractive for klydonograph measurements, its use is not justified because it does not give the accurate results which may be obtained with the pipe-type or ring-type potentiometer. F. C. Hanker explained that, although important information has been obtained through the use of the klydonograph, this instrument does not give data on the time relation of the voltages. He stated his company, in cooperation with the Aluminum Company of America, is making a lightning investigation by means of a portable cathode-ray oscillograph, which will give sufficient data to establish the complete wave form of a surge with reasonable accuracy. A. O. Austin commented on the value of records which take time into account, drawing attention to the fact that at the present time we do not know what effect voltage and time have on the phenomenon of flashover. M. I. Gross stated that some of the data obtained in his experiences seemed to indicate a much higher attenuation on lightning surges than the value given in the equation in Mr. Lewis' paper. Commenting on the same formula, J. H. Foote asked if further investigation would not show that the formula should include a term or factor which takes wave front into account. He doubted that the equations in Mr. Sporn's paper, regarding the effectiveness of choke coils, are entirely justified by the data. He claimed that it seems illogical to isolate station equipment from the arrester by means of a choke coil, as the arrester is usually employed to protect station equipment. Harold Michener pointed out that on the system of the Southern California Edison Company ground wires had not given as satisfactory results as reported in the papers. He named several instances in which ground wires had not seemed to protect the lines. E. S. Fields called attention to a device which has been employed on the lines of the Union Gas and Electric Company to eliminate a tripout of the line in case of flashover. In the scheme he mentioned, a standard grading ring is installed at the bottom of the insulator string and at the top are placed two expulsion fuses instead of the conventional metal horn or ring. He declared that this device is very satisfactory for interrupting the arc before the relays have time to operate. In discussing ground wires A. O. Austin stated that it might be found desirable to sectionalize the ground line and ground it through a resistance. Some kind of resistance is needed in a ground wire, he said, to absorb energy from the power wires and thus decrease the dangerous effects of surges. In answering a question by L. L. Perry, W. W. Lewis said that the oxide-

film arrester limits the voltage to about 1 kv. per cell to 1.8 kv. per cell, depending upon the wave front, the higher value being for the steepest wave fronts. In commenting on Mr. Michener's discussion, he pointed out that the usefulness of a ground wire depends largely on the resistance of the tower footing. J. R. Eaton emphasized the necessity of grounding a line at the point where men are working on it, stating that he had recorded over 35,000 volts at the middle of a span of a ground wire which was, of course, grounded at both ends.

Session B—Technical Committee Reports

1. *Research*, F. W. Peek, Jr., Chairman.
2. *Electrophysics*, Vladimir Karapetoff, Chairman.
3. *Instruments and Measurements*, E. S. Lee, Chairman.
4. *Communication*, H. W. Drake, Chairman.
5. *Production and Application of Light*, P. S. Millar, Chairman.
6. *Electrochemistry and Electrometallurgy*, G. W. Vinal, Chairman.
7. *Electrical Machinery*, F. D. Newbury, Chairman.

These reports were presented as indicated. No discussion was contributed from the floor.

Session C—Technical Committee Reports

1. *Power Transmission and Distribution*, Philip Torchio, Chairman.
2. *Protective Devices*, F. L. Hunt, Chairman.
3. *Automatic Stations*, Chester Lichtenberg, Chairman.
4. *General Power Applications*, A. M. MacCutcheon, Chairman.
5. *Applications to Mining Work*, W. H. Lesser, Chairman.
6. *Applications to Marine Work*, W. E. Thau, Chairman.
7. *Transportation*, J. V. Duer, Chairman.
8. *Electric Welding*, J. C. Lincoln, Chairman.

In referring to the Report of the Committee on Power Transmission and Distribution, D. W. Roper pointed out that the 132-kv. oil-filled cable installed in Chicago and New York had operated for a year with no electrical failures. He explained the origin and prevention of the red oxide of lead which has been found on underground cables in certain locations. This oxide, he declared, is formed by water seeping on the cable sheath through concrete which has not set perfectly. This water contains sodium and calcium hydroxides which attack the lead. He recommended that concrete used around cables should be allowed to set at least a month and that it should be exposed during that time to air. He explained that the presence of carbon dioxide, as well as air, is quite necessary for the proper setting of concrete. In fact he had applied carbon dioxide to accelerate the setting. In discussing the same report Harold Michener claimed that the subject of conductor vibration should be strongly emphasized, both for power wires and for ground wires. He stated that his company had eliminated vibration by means of dampers or weights hung in the span and that he believed that this method is preferable to placing an arrangement at the point of contact in order to decrease the deteriorating effect of the vibration. In a written discussion M. T. Crawford stated that on some lines in the Puget Sound Region where lightning is comparatively infrequent and where wood poles are used the results of records over three years indicate that ground wires are not economically justified.

In a written discussion on the Report of the Committee on Protective Devices, K. B. McEachron outlined the reasoning on which the proposed standards for lightning arresters are based.

Session on High-Speed Circuit Breakers as Applied to Electrified Railways

1. *High-Speed Circuit Breakers*, J. W. McNairy.
2. *High-Speed Circuit Breakers for Railway Electrification*, H. M. Wilcox.
3. *Operating Experience with High-Speed Circuit Breakers*, B. F. Bardo.
4. *Arrangement of Feeders and Equipment for Electrified Railways*, R. B. Morton.
5. *Protection of Electric Locomotives and Cars to Operate with High-Speed Circuit Breakers*, E. H. Brown.
6. *The High-Speed Circuit Breaker in Railway Service*, W. P. Monroe and R. M. Allen.

In discussing Mr. McNairy's paper, F. C. Hanker questioned the statement that in neighboring communication circuits the induced voltage from railway systems will be more frequent and of larger magnitude than the disturbances set up by an ordinary power circuit. He claimed that, though undoubtedly such disturbances occur with greater frequency on a railway system, the voltage for an equal exposure is higher on the power system. He believed that Mr. McNairy's statements were made on the basis of unequal exposures. Mr. Hanker and also H. C. Graves in a written discussion, pointed out why selective relaying is necessary on railway systems and why simple over-current relays are inadequate. The reason for this condition, they explained, is that on parallel lines the fault current at one time may be considerably less than the load current at other times. It was suggested that an impedance type of relay would prove satisfactory in overcoming this obstacle. Sidney Withington in a written discussion stated that the high-speed breakers used by the New York, New Haven and Hartford Railroad, which were the first of their type to be placed in commercial operation, had been very satisfactory. He stated that the installation has been of particular value in quickly clearing grounded circuits and thus preventing inductive effects on closely paralleling communication circuits.

In discussing Mr. Brown's paper P. H. Hatch said that on most electric railroads using alternating current the circuit breakers are employed essentially as oil switches and that some method, therefore, is necessary for protecting locomotives or cars against the disastrous effects of short circuits in the high-tension apparatus. On the New Haven Railroad, he said, this has taken the form of a time-element relay so adjusted that the circuit breakers on the locomotives or cars, in case of short circuit, will not operate until after the sectionalizing breakers in the feeder and trolley circuits have tripped. He suggested that some arrangement for isolating a short circuit on a unit of rolling stock might be developed, which would combine the advantages of lowering the pantograph automatically and at the same time introduce a definite time element between this operation and the appearance of the short circuit, which would give the sectionalizing breakers time to act.

Caesar Antoniono disagreed with the recommendation in Mr. Wilcox's paper to use a solid butt contact without auxiliary arcing tips. He stated that blisters caused by the opening of such a breaker will prevent its satisfactory closing. In commenting on the Monroe and Allen paper, he said that mechanically latched breakers are preferable in some cases to breakers which are held closed magnetically,—this being particularly true where breakers must be reclosed under low-voltage conditions on the system. In a written discussion H. B. West pointed out that the high-speed interruption of current from a synchronous converter is likely to cause flashover. He suggested as a remedy that the high-speed breaker be applied to shunt a current-limiting resistor in series with the machine. Opening of the high-speed breaker thus reduces the current to a value usually two or three times the machine rating and the circuit is then completely interrupted by another breaker of ordinary speed.

In discussing Mr. McNairy's paper, J. B. MacNeill drew attention to some of the advantages of the oil circuit breaker, as compared with air breakers. He stated that oil breakers will give service continuity and maintenance cost comparable to air breakers; that they occupy a volume of approximately one-third of air breakers; that they may be easily insulated for higher voltages, and that they will handle larger amounts of energy. In connection with Mr. Antoniono's objection, he stated that

solid contacts have been used with very satisfactory results for four years. Chester Lichtenberg brought out the point that the high-speed circuit breaker should always be located on the negative side of d-c. machines, as this will greatly lessen the tendency to flashover.

TECHNICAL SESSION E

1. *A Formula for Minimum Horizontal Spacing of Transmission-Line Conductors*, P. H. Thomas.

2. *Transmission Experiences of the Public Service Co. of Colorado*, M. S. Coover and W. D. Hardaway.

3. *A-c. Elevator Motors of the Squirrel-cage Type*, R. E. Dreese.

4. *Electric Welding of Pipe Lines*, J. D. Wright.

In discussing the paper by Mr. Thomas, M. G. Lloyd took exception to the accuracy of the formulas under certain conditions, especially as regards the effects of various span lengths. He also suggested that more practical results would be obtained by employing the square root of the sag rather than the first power.

M. T. Crawford, in a written discussion on the paper by Messrs. Coover and Hardaway, cited some experiences on a 120-mile, 110-kv. line of the Puget Sound Power and Light Company, which extends across the Cascade Range. In this line no dead-ends are employed, in order to eliminate troubles which were experienced from wires being jerked in two at dead-ends by the falling off of large sections of snow and ice, which builds up to two feet in diameter on the line. All of the diagonal and horizontal angles have been removed from the steel towers up to the snow line, in order to eliminate the serious trouble which was formerly encountered by the bending and shearing of the angle braces by the settling of the heavy snow crust in the Spring. He said that only six interruptions have occurred on this line in five years, two of which were from lightning, though lightning is infrequent in this region. G. B. McCabe stated that the Detroit Edison Company has found properly built ground wires very effective. On one double-circuit, 120,000-volt line during 1926 there were 44 lightning storms and 107 tripouts. In 1927 after a single ground wire had been installed there were only 7 tripouts, though the number of lightning storms was 37. Answering a question of Mr. Michener, W. D. Hardaway said that he thought the conductor failures experienced on the line described in his paper were caused by the ground wire being blown into the conductor which burned in two or was damaged and failed later.

In a written discussion on the paper by J. D. Wright, J. F. Lincoln mentioned another outstanding example of pipe welding, namely the Mokelumne River Line, ninety miles in length and containing 78,000 tons of steel. This line was welded with the carbon-arc process. He claimed that in the manufacture of pipe the cost of welding is less than one per cent and that all necessary development in welding methods has been done. Further cost reductions should be made in the other operations J. C. Lincoln pointed out that where riveted joints are used in pipe which carries water travelling at high velocity corrosion is likely to occur at the rivets. At such points a partial vacuum is formed, which assists in destructive chemical action. This statement was corroborated by R. E. Barnard and H. J. Lawson. Mr. Lawson also told of considerable successful experience which he had in repairing runners and water wheels by means of electric welding.

TECHNICAL SESSION F

1. *Utilization of Lodgepole Pine as Pole Timber*, R. W. Lindsay.

2. *Carrier Systems on Long Distance Telephone Lines*, H. A. Affel and C. S. Demarest.

3. *Superimposed High-Frequency Currents for Circuit-Breaker Control*, L. R. Ludwig.

4. *Extinction of an A-C. Arc*, Joseph Slepian.

C. S. Demarest contributed additional information to that in the second paper and pointed out the difficulties which arise in carrier telephone systems on account of the relatively high frequencies and large power-level differences which are employed. Excessive losses from these causes, as well as cross talk, must be avoided by special grouping of equipment and wiring and by use of shielded cable and apparatus.

In a written discussion, commenting on Mr. Ludwig's paper, O. C. Traver pointed out that atmospheric static and steep wave fronts might cause imperfect operation of the equipment described. He suggested also that the use of the rate-of-rise relay might cause the 500-cycle generators to fall out of step. R. G. McCurdy, in a written discussion, stated that the use of high-frequency currents for control might cause a considerable increase in noise interference on exposed telephone circuits under normal power-circuit conditions. He stated that from the standpoint of inductive coordination it is important that either (1) the continuous use of the high frequency be avoided or (2) the control currents, if continuous, be at such frequencies and power levels as not to interfere with adjacent communication circuits. D. W. Roper asked if the system described can be used for the protection of underground, high-potential tie lines between generating stations. Paul MacGahan stated that the system is probably not desirable at the present time except for cases that cannot be handled by means of the present accurate over-current, directional or impedance relays. G. B. Dodds agreed that this scheme has one great advantage, in that it may be tested without actually drawing current from the power line. He warned, however, that considerable attention should be given to the reliability of the equipment, so that this addition to a system would not create an extra hazard. He thought that with such a system some sort of backup protection would be necessary.

Discussing Dr. Slepian's paper, R. W. Sorensen said that laboratory tests have corroborated the theoretical developments in the paper. R. M. Spurck stated that experience and test results with circuit-breaker operation seem to substantiate many of the points in the paper. C. D. Ainsworth in a written discussion, agreed on this point, pointing out particularly how the multi-break circuit breaker accomplishes some of the desirable functions mentioned in the paper.

CONFERENCE OF OFFICERS AND DELEGATES

In accordance with past practise, the first day of the Convention, Monday, June 25, was devoted to a Conference of Officers and Delegates held under the auspices of the Sections Committee and the Committee on Student Branches.

Forty-six of the fifty-three Sections were represented by Delegates, seven of the Geographical Districts were represented by their Secretaries, and the Chairmen of eight District Committees on Student Activities were present. In addition to the Delegates a considerable number of officers-elect and other interested members were present.

The first session of the Conference convened at 10:15 a. m., with Doctor W. B. Kouwenhoven, Chairman of the Sections Committee, presiding. During the early part of the afternoon two sessions were held in parallel, Doctor Kouwenhoven presiding over the part dealing with Section activities, and Vice-President J. L. Beaver, Chairman of the Committee on Student Branches, presiding over that dealing with Student activities. During the last hour the two groups met together again to discuss Section and Branch cooperation and related subjects.

The following is a summary of the program which had been prepared in advance by a special committee and mailed to all Delegates:

Announcements by Doctor W. B. Kouwenhoven, Chairman of Sections Committee

Remarks by President Gherardi

Remarks by Presidential-Nominee Schuchardt

Remarks by National Secretary Hutchinson

Section Activities and Policies

Résumé of Section questionnaire and conclusions, costs of Section meetings, and general discussion.

Regional Meetings

Topical presentation by five speakers and general discussion.

Afternoon Sessions

(sessions A and B in parallel)

A—Sections, Doctor Kouwenhoven presiding.

Obligation of Sections to public and civic relations, broadcasting of Section programs, distribution of membership, local membership, attendance at meetings, Annual Report on Section Activities, and general discussion.

B—Branches, Vice-President Beaver presiding.

Branch problems and programs, Branch dues, entrance fees, prizes for Student papers, Student conventions, classes of schools at which Branches may be organized, appointment and duties of Counselors, and general discussion.

General—Doctor Kouwenhoven presiding.

Resumé of Branch questionnaire and conclusions, Section and Branch cooperation, and general discussion.

Resumés of the Annual Report on Section and Branch Activities, prepared by an Editing Committee, as a result of a recommendation made at the Conference held at Detroit on June 20, 1927, were presented by Mr. I. Melville Stein, Chairman of the Editing Committee. Favorable comments were made upon the form of the Report and the following recommendations of a special committee, composed of Professor Harold B. Smith, Chairman, I. M. Stein, and C. R. Wallis, appointed at the morning session, were adopted:

"First, that a further trial of the present plan be carried out for a period of not less than two years in order to obtain more experience on which to base a more permanent policy.

"Second, that one item of the next questionnaire be designed to bring out the reaction of the Sections on this plan.

"Third, that the monthly report for Sections be revised to provide all statistical data needed for the Annual Report.

"Fourth, that the annual questionnaire sent out in connection with the Annual Report be limited to obtaining information not available from revised monthly report forms and from the statistics of the Membership Committee."

In addition to the session on Monday afternoon, the Counselor Delegates and others especially interested in Student activities held a session Monday evening and another on Wednesday morning. Many subjects relating to Student enrolment in the Institute, Branch meetings, Student conventions, etc., were discussed and those present considered the meetings very beneficial because they brought out the viewpoints of men active in Student Branch affairs in many parts of the country.

A report on the Conferences will be printed in pamphlet form and mailed to all Delegates in attendance and to national, District, Section, and Branch officers. Any Institute member who is interested in the proceedings may obtain a copy of the pamphlet, without charge, upon application to Institute headquarters, New York.

A. I. E. E. Directors Meeting

The regular meeting of the Board of Directors of the American Institute of Electrical Engineers was held at the Cosmopolitan Hotel, Denver, Colorado, on Wednesday, June 27, 1928.

There were present: President Bancroft Gherardi, New York, N. Y.; Vice-Presidents, J. L. Beaver, Bethlehem, Pa., A. B. Cooper, Toronto, Ont., O. J. Ferguson, Lincoln, Neb., B. G. Jamieson, Chicago, Ill., E. R. Northmore, Los Angeles, Calif., H. H. Schoolfield, Portland, Ore.; Managers J. M. Bryant, Minneapolis, Minn., F. J. Chesterman, Pittsburgh, Pa., H. C. Don Carlos, Toronto, Ont., M. M. Fowler, Chicago, Ill., F. C. Hanker, East Pittsburgh, Pa., E. B. Meyer, Newark, N. J.; National Secretary F. L. Hutchinson, New York, N. Y. By invitation: officers-elect R. F. Schuchardt, Chicago, Ill., B. D. Hull, Dallas, Tex., W. T. Ryan, Minneapolis, Minn., A. M. MacCutcheon, Cleveland, Ohio, and Assistant National Secretary H. H. Henline, New York, N. Y.

The minutes of the Directors meeting of May 18, 1928, were approved.

Reports were presented of meetings of the Board of Examiners held May 24 and June 13, 1928, and the actions taken at those meetings were approved. Upon the recommendation of the Board of Examiners the following actions were taken: 96 Students were enrolled; 175 applicants were elected to the grade of Associate; 26 applicants were elected to the grade of Member; one Member was reinstated; one applicant was elected to the grade of Fellow; 86 applicants were transferred to the grade of Member; seven applicants were transferred to the grade of Fellow.

Approval by the Finance Committee for payment, of monthly bills amounting to $27,808.44, was ratified.

The annual report of the National Treasurer, for the fiscal year ending April 30, 1928, was received and ordered filed.

In accordance with Section 22 of the Constitution, the following members were made "Members for Life" by exemption from future payment of dues: Messrs. Edward C. Acheson, Harry Alexander, James H. S. Bates, Charles N. Black, C. Billberg, Douglass Burnett, H. E. Chubbuck, A. C. Crehore, M. M. Davis, W. K. Dunlap, J. P. Edwards, William Elmer, George A. Hamilton, John W. Howell, Frank Land, J. R. Lovejoy, L. B. Marks, Julius Meyer, W. A. Mosscrop, Clayton W. Pike, R. A. Ross, L. B. Stillwell, Charles A. Terry, Charles F. Uebelacker, F. Uhlenhaut, Jr., Edwin R. Weeks, W. F. White, and W. G. Whitmore.

It was also voted to apply the designation "Member for Life" to those who are eligible but who prefer to continue to pay dues until further notice.

Upon the recommendation of the Committee on Student Branches, authority was granted for the organization of a Student Branch of the Institute at the University of South Carolina.

Approval was given to the admission to membership in the American Engineering Standards Committee of the National Machine Tool Builders Association.

The resignation of Mr. Calvert Townley as an Institute representative on the Board of Trustees of the United Engineering Society was presented and accepted, and Mr. H. P. Charlesworth was appointed to fill his unexpired term.

By-laws governing the organization of the Lamme Medal Committee were adopted and a plan of making awards of the medal was approved.

Because of the vacancy in the Board of Directors caused by the election of Mr. H. A. Kidder to the office of Vice-President, taking effect August 1, Mr. Charles E. Stephens, District Manager, Westinghouse Electric & Manufacturing Company, New York City, was unanimously elected to fill the unexpired term of Mr. Kidder as Manager, ending August 1, 1929.

Other matters were discussed, reference to which may be found in this and future issues of the Journal.

The meeting closed with a unanimous vote of appreciation to President Gherardi for his effective services on behalf of the Institute during the past year. Other matters of importance were considered, as announced elsewhere in this issue of the Journal.

Institute Prizes for Papers Awarded

The prizes for papers presented during 1927 awarded by the Committee on Award of Institute Prizes, were presented on June 26 at the annual business meeting held in connection with the Summer Convention at Denver. Certificates of award were given to each winning author and a cash prize of $100 was presented for each paper, this prize being divided in case of joint authorship. The report of the committee is in part as follows:

In the field of engineering practise the committee considers the outstanding contribution during the year is the paper on 132,000-volt cables, and therefore makes the following award:

First Prize—Engineering Practise

132,000-Volt Single-Conductor Lead-Covered Cable, by Philip Torchio, L. Emanueli, W. S. Clark, A. H. Kehoe, C. H. Shaw, J. B. Noe and D. W. Roper, presented at the Chicago Regional Meeting, November 28-30, 1927.

In the field of theory and research the committee found a particularly large number of excellent papers. In awarding the prize the committee feels that favorable mention should be made of the entire group of five papers on "Television" presented at the 1927 Summer Convention of which the prize paper forms a part. The award is as follows:

First Prize—Theory and Research

The Production and Utilization of Television Signals, by Frank Gray, J. W. Horton and R. C. Mathes, presented at the Summer Convention, Detroit, June 20-24, 1927.

In addition to the prize papers mentioned above, the committee has awarded honorable mention to two outstanding papers as follows:

Honorable Mention

Static Stability Limits and the Intermediate Condenser Station, by C. F. Wagner and R. D. Evans, presented at the Pacific Coast Convention, Del Monte, Cal., Sept. 13-16, 1927.

A New Electronic Rectifier, by L. O. Grondahl and H. P. Geiger, presented at the Winter Convention, New York, Feb. 7-11, 1927.

As a result of consideration of the papers eligible for the initial paper prize, the committee has made the following awards.

Initial Paper Prize

Movements of Overhead Conductors During Short Circuits, by W. S. Peterson and H. J. McCracken, Jr., presented at the Los Angeles Section meeting, Dec. 6, 1927.

Initial Paper—Honorable Mention

Methods Used in Investigating Corona Loss by Means of the Cathode-Ray Oscillograph, by W. L. Lloyd, Jr. and E. C. Starr, presented at the Summer Convention, Detroit, June 20-24, 1927.

As a result of their study of the papers eligible for the Branch paper prize, the committee made the following awards.

Branch Paper Prize

Calculation of Stray Load Losses by G. H. Rockwood, Jr., presented at the Student Session of the Pittsfield Regional Meeting, May 27, 1927.

Branch Paper—Honorable Mention

The Localization of Faults on Parkway Cable, by J. A. Sargent, presented at the Student Session of the Chicago Regional Meeting, November 28, 1927.

The committee which made the awards was composed of Messrs. H. P. Charlesworth (Chairman), E. B. Meyer and F. W. Peek, Jr.

Acceptance Standards and Service Recommendations

The principal function of the A. I. E. E. Standards is to provide a set of rating specifications and acceptance tests which may be used as a basis for the purchase of machines and apparatus. With these Standards one may make an analysis and form a judgment of the comparative merits of apparatus built by different manufacturers.

In formulating these Standards, there has been some difficulty and some confusion at times in attempting to separate operating characteristics from those characteristics and conditions which are inherently a definite part of purchase acceptance tests. The suggestion has been made repeatedly—in fact, it has developed into a definite demand—that operating conditions which may be permitted for each class of apparatus, be incorporated in the Standards, and it is a well supported opinion that they be separated from those Standards which become part of a purchase contract between manufacturer and user. To date this plan has not been carried out.

For the purpose of comparing bids, the various characteristics of machines and the tests necessary to check them, must be outlined. The conditions of the acceptance test may or may not be the conditions under which the apparatus is to be operated in service. It is important then to the user that he have something to guide him in the loading of his apparatus if the operating conditions are different from those specified in the acceptance test.

A very important beginning has been made in this direction in connection with the Standards for Transformers, Induction Regulators and Reactors. It is proposed to add to that section, No. 13, an appendix which outlines some of the possibilities of operation in actual service when the ambient temperature is different from the standard ambient specified in connection with ratings.

This is considered to be a very important innovation in A. I. E. E. standardization work—one which may be useful enough to be extended to other classes of apparatus. For this reason, special attention is called to the proposed appendix, and those interested are requested to send in their comments, suggestions and criticisms to H. E. Farrer, Secretary of A. I. E. E. Standards Committee, 33 West 39th St., New York, N. Y., in order that that Committee may have the advice and counsel of all interested parties before this innovation is put into final effect. The proposed appendix is as follows:

A. I. E. E. TRANSFORMER STANDARDS, SECTION 13
Proposed Appendix

RECOMMENDATIONS FOR THE OPERATION OF TRANSFORMERS, INDUCTION REGULATORS AND REACTORS

13-600 Limiting Observable Temperature of Oil.—The oil in which apparatus is permanently immersed should under no circumstances have a temperature, observable by thermometer, in excess of 90 deg. cent.

13-601 Operation at Rated Load.—Apparatus conforming with the Standards for rating is suitable for carrying rated load continuously provided that the temperature of the cooling medium does not exceed 40 deg. cent. for air or 25 deg. cent. for water.

13-602 Operation with Cooling Air and Water Exceeding 40 Deg. Cent. and 25 Deg. Cent. Respectively.—For apparatus conforming with the Standards for rating, the load should be reduced 2 per cent below the rated load for each degree that the temperature of the cooling air exceeds 40 deg. cent. or that the temperature of the cooling water exceeds 25 deg. cent. However, the use of apparatus in cooling air exceeding 50 deg. cent. or in cooling water exceeding 35 deg. cent. shall be considered as special.

13-603 Operation at Loads Greater than the Rated Load.*

(*a*) *Apparatus Not Equipped with a Winding-Temperature Indicator*:—Apparatus not equipped with a winding-temperature indicator may be loaded continuously 1 per cent above rated load for each degree centigrade that

*Since the operation of apparatus at loads greater than rated load increases the probability of maintaining the limiting temperature for a greater portion of the time, and because the life of insulation is a function of both its temperature and the time of subjection to that temperature, the operating temperature of the winding should be limited to a lower value than for operation in which the rated load is never exceeded.

Also, under these conditions, the temperature difference between the observable temperature and the hottest spot temperature increases.

For these reasons, the limits specified in Para. **13-603** which are 10 deg. cent. lower than the highest observable temperature recognized for apparatus whose rated load is never exceeded, have been agreed upon for purposes of standardization.

the temperature of the cooling medium is below 30 deg. cent. for air or 25 deg. cent. for water.

Thus, for example, when the temperature of the cooling medium is 0 deg. cent., the permissible continuous load is 130 per cent of rated load for air-cooled apparatus and 125 per cent of rated load for water-cooled apparatus.

Loads greater than 130 per cent of rated load for air-cooled apparatus or 125 per cent of rated load for water-cooled apparatus shall not be applied under any conditions even though the temperature of the cooling medium be lower than 0 deg. cent.

(*b*) *Apparatus Equipped with a Winding-Temperature Indicator*:—Apparatus equipped with a winding-temperature indicator may be loaded continuously in excess of rated load provided the indicated winding-temperature does not exceed the following limits:—

For indicators marked in terms of

Hottest-spot Temperature..................95 deg. cent.
Embedded Detector Temperature...........90 deg. cent.
Resistance Method Temperature...........85 deg. cent.

(*c*) *Oil Temperatures*:—Oil temperature alone is an inadequate criterion of the winding temperature because of the increased temperature drop through the insulation at low temperatures of the cooling medium and of the time lag between the winding and oil temperatures. Loading apparatus on the basis of oil temperature alone as a guide is not recognized by the A. I. E. E.

13-604 **Conditions Affecting Constructional or Protective Features.**—There are conditions which, while not usually affecting the rating, may require special consideration, principally with respect to constructional or protective features. Where such conditions exist it is recommended that they be brought to the manufacturer's attention.

Among such conditions are:

(a) Exposure to damaging fumes
(b) Operation in damp places
(c) Exposure to excessive dust
(d) Exposure to gritty dust
(e) Exposure to steam
(f) Exposure to excessive oil vapor
(g) Exposure to explosive gases
(h) Exposure to salt air
(i) Exposure to abnormal vibration or shocks.

Redetermination of Values of Electrical Units

It has been known for some years that the values assigned to the international electrical units (ohm, ampere and volt) do not conform accurately with the absolute values of these units as defined in the c. g. s. system. These discrepancies exist owing to the limitations in accuracy of measuring methods which obtained when the present values were legalized. With the degree of precision now available in electrical measurements, the difference between the statutory and the fundamental values of these units has become apparent and is too large to comply with the precision now attainable in the use of fundamental standards. A determination of these statutory values is therefore highly desirable.

The following resolutions were prepared by the Committee on Instruments and Measurements, approved by the Standards Committee, and adopted by the Board of Directors at Denver, June 27, 1928. Copies of the resolutions have been transmitted by the Standards Committee to the Committee on Manufactures of the U. S. Senate, and to the Committee on Coinage, Weights and Measures of the U. S. House of Representatives. They have also been sent to the U. S. Bureau of Standards, and to the national standardizing laboratories of England, France, Germany, Japan and Russia.

Resolutions on Revision of Electrical Units

Whereas, there is conclusive evidence that there are discrepancies between the statutorily established international electrical units (ohm, ampere, and volt) and the fundamental ohm, ampere and volt, which the international units were intended to represent, these discrepancies in the case of the ohm and the volt amounting to approximately one-twentieth of one per cent; and

Whereas, differences of this magnitude are objectionably large in comparison with the precision required and now being attained in the construction and use of standards fundamental to all electrical measurements; therefore be it

Resolved, that the American Institute of Electrical Engineers hereby urges the Bureau of Standards and foreign national standardizing laboratories to undertake, as soon as possible, the additional researches necessary in order that legislation to reduce these discrepancies to within acceptable limits may be enacted in the near future.

And Whereas, the present electrical units are defined by statute in terms of material standards, namely, the mercury ohm and the silver voltameter, which it is now known only approximately represent the absolute ohm and ampere and which experience has shown to have serious limitations, and

Whereas, such progress has been made in recent years in the art of making absolute electrical measurements in terms of the fundamental units of length, mass, time, and space permeability that the accuracy and reproducibility of a system of electrical units realized by such absolute measurements would seem to be adequate for commercial, industrial and scientific purposes; and

Whereas, the legalization of the absolute ohm and ampere and the units derived from them, (these units to be realized by the national standardizing laboratories) would avert the recurring proposals for revision of the values of the legalized units, and would establish the electrical units on a permanent legal basis, therefore be it

Resolved, that the American Institute of Electrical Engineers hereby urges the Bureau of Standards and foreign national standardizing laboratories to undertake, as soon as possible, the additional researches necessary in order that the absolute ohm and absolute ampere based on the centimeter-gram-second electromagnetic system, with the absolute volt, watt and other units derived from them, may be legalized in place of the international ohm and ampere and their derived units.

Resolved, further, that in order to avoid the confusion which would result from an interim use of new empirical units based on corrected values of the international units, the international electrical units should be continued in effect without any readjustment of values until such time as the practicability of legalizing the above-mentioned absolute units shall have been determined.

Resolved, further, that copies of these resolutions be communicated to the various national standardizing laboratories and other interested bodies, by the Standards Committee.

The Lamme Medal

The late Benjamin G. Lamme, Chief Engineer of the Westinghouse Electric & Mfg. Company, who died on July 8, 1924, made a bequest to the Institute to provide for the award of a gold medal (together with a bronze replica thereof) annually to a member of the Institute—"who has shown meritorious achievement in the development of electrical apparatus or machinery,"— with the further provision that two such medals may be awarded in some years if the accumulation from the funds warrants.

An agreement was entered into between the executors and trustees of Mr. Lamme's last will and testament and the Institute. A Special Committee, with Professor Charles F. Scott of Yale University as Chairman, was appointed to supervise the design of the Medal, the preparation of the dies, and the formulation of rules for the award of the Medal.

By-laws formulated by this Special Committee, providing for a Lamme Medal Committee of nine members and containing all necessary rules for its guidance, were approved by the Board of Directors on June 27.

Special attention is called to the fact that names of members of the Institute who are considered suitable candidates for the

Lamme Medal may be submitted by any member, in accordance with Section 1 of Article VI of the By-laws, which is quoted below.

"The Committee shall cause to be published in one or more issues of the A. I. E. E. JOURNAL each year, preferably including the June issue, a statement regarding the 'Lamme Medal' and an invitation for any member to present to the National Secretary of the Institute by September 1 the name of a member as a candidate for the Medal, accompanied by a statement of his 'meritorious achievement' and the names of at least three engineers of standing who are familiar with the achievements."

The Louvain Dedication

On July 4th, in the presence of Prince Leopold, dignitaries of State, Church and University, and delegates and members of various engineering societies, the new library of the Louvain University was dedicated, the Belgian people on every hand demonstrating their reciprocation of the friendliness expressed in the American gift contributed by more than 500,000 persons from all parts of the United States. "In the atmosphere of Louvain all rival clamor ceased and the sciences and humanitaries blended their individual pretentions in harmony with eternal verities that surround such consecrated places. Here, therefore, it was fitting that the American engineer should set a symbol that will speak for ages of his delight in helping to restore this seat of beauty, learning and leadership in his own engineering sphere as well." At 1:30 p. m. a stately cortege left the Halls of the University, proceeding through streets decorated with Belgian and American flags and thronged with cheering crowds, to the large Place du Peuple which the new library faces. The general mass was estimated at least 10,000 persons, made up of officers and faculty members of the University, officers of the Government, dignitaries of the church and the American guests, and preceded by a company of mediaeval trumpeters. In the middle of the square in a clear space about 100 ft. wide and 300 feet long, with a circle of flowering plants at its center, was raised a covered dias with the speaker's stand and microphone at the opposite end. To the dais were escorted the American Ambassador and Mrs. Gibson, Ministers of the Belgian Government, the Rector Magnificus and other officers of the University of Louvain, Cardinal Van Roey, representatives of the Commission for Relief in Belgium and members of the Committee on War Memorial to American Engineers, consisting of Edward Dean Adams, Chairman of the American Committee, representing Engineering Foundation and Engineering Libraries, George W. Fuller, representing the American Society of Civil Engineers, Arthur S. Dwight, representing the American Institute of Mining and Metallurgical Engineers, Charles M. Schwab, representing the American Society of Mechanical Engineers, Arthur W. Berresford, representing the A. I. E. E., George Gibbs, representing United Engineering Society, L. R. Lohr, representing the Society of American Military Engineers, Roy V. Wright, President of the United Engineering Society, and Alfred D. Flinn, Secretary.

At the corners of the stand were placed the four flags; one from the Belgian War Relief Commission; one from the senior national Societies of the United States; a third from the Society of American Military Engineers, (given by Col. Arthur S. Dwight of the Eleventh Engineers); and a fourth—a United States standard regimental flag given by Major L. R. Lohr, of the Corps of Engineers, U. S. Army. Beyond were many colorful flags of Belgian military organizations, and the heralds, in mediaeval armor.

When all were in place, the Prince and Princess appeared as representatives of the King and Queen, and occupied the central front seats amid many manifestations of their popularity. After a portion of the program relating to the building had been completed by the delivery of the keys by the architect, Whitney Warren of New York, the Committee on War Memorial to American Engineers presented the clock, the carillon and the maintenance fund of $10,000. Mr. Arthur W. Berresford, Past-President of the Institute then delivered the Deed of Gift and Trust and Secretary Alfred D. Flinn presented the Memorial Record Volume, one of the finest specimens of American bookmaking, beautifully bound in hand-tooled leather and made of paper called Shidzuoka vellum, chosen for durability and strength and made by the Japanese Imperial Government mills from the inner fiber of mulberry. This book contains the Honor Roll of approximately 2500 engineers and engineering assistants in the United States who gave their lives in the Great War, the memorial inscriptions which appear on the great "Liberty Bell of Louvain," a list of the contributors to the fund and other information about the memorial. At the banquet served later, a replica of this bell, 24 inches in diameter was presented by Chairman Adams to be placed in the University's reading room or other location convenient to visitors who may be unable to climb the 165 feet of the tower to see the bell itself.

The blessing of the building and the bells by Rector Ladeuze, accompanied by beautiful music was made audible to the vast assembly by means of a loud-speaker skillfully concealed in the tower. This was followed by cantatas sung by a host of school children. With Rector Ladeuze occupying the chair, Secretary Van der Eessen of the University escorted the speakers one by one from the dais to the platform and back to the dais. Early in the program Ambassador Gibson presented the Library building, on behalf of the American donors, and delivered its keys to Rector Ladeuze.

Edgar Ricard, Colonel Dwight and Major Lohr presented the four flags previously mentioned, to be carried later in the procession into the Library hall in which they are to permanently hang. Toward the end of the ceremony, Chairman Adams, Arthur W. Berresford, and Secretary Alfred D. Flinn, accompanied by two pages, the young sons of Prof. Albert Van Hecke, were escorted to the platform. They carried the address of presentation for the carillon, clock and maintenance fund, printed in French on a scroll and signed by all members of the Committee; the Deed of Gift and Trust in duplicate, handsomely bound in red levant leather—and the large Memorial Record Book, bound in green levant leather as described and containing the names of more than 2500 names of American engineers. When this group returned to the dais, the Prince and Princess arose, greeted them graciously and with extended hands, expressed to Chairman Adams their appreciation of the gift. There was a well-timed pause in the program as the great Bourden bell of the carillon of the memorial clock struck the hour of three and the famous carillonneur, Josef Denyn played the Belgian National air.

Immediately after the ceremonies, there was an inspection of the interior of the Library, during which a bronze bust of Herbert Hoover "in recognition of his humanitarian services to Belgium during the War and since" was unveiled. This bust was the work of Suzanne Silvercruys Farnum, sculptress.

In the evening at a banquet attended by engineers and others at the dedication ceremonies, Chevalier Josef Denyn, called the Dean of Carillonneurs, played a concert on the new Louvain carillon, his numbers being intersperesed with songs by the Legia, the first choir of singers of Belgium.

At the close there was an address of appreciation by Rector Ladeuze to the many guests of the several countries and a brief response by Laurence V. Benet, (A. S. M. E.) for the American engineers. The 377-pound replica of the bell was placed on the Library table by Doctor Adams, the 8-ton Bourdon bell of the carillon was tolled for the first time, and the company dispersed to the notes of a fanfare by the trumpeters followed by the soft playing of the carillon by Chevalier Denyn continuing into the twilight.

Fireworks at ten o'clock illuminated the magnificent Tower of the Library.

On the fifth of July three receptions were given for the American vistors in Brussels. At 2:30 p. m. the Burgomaster received a large party in the ancient City Hall and had the guests escorted through the finely proportioned, richly decorated rooms with their priceless paintings. At 4:30 p. m. the engineers were entertained by the Central Committee of Belgian Industries in its commodious quarters and there were friendly exchanges of information about the industries of Belgium and the United States. In the evening a concert and dance were given at the Residence Palace, attended by the Prince and Princess. During intermission in the program the representatives of the Commission for Relief in Belgium and the delegates of the American engineering societies, with their ladies, were individually presented by Ambassador and Mrs. Gibson to the Prince and Princess.

On the sixth of July, the last of the American engineers departed with memories crowded full of happy recollections of many delightful friendly contacts with our Belgian neighbors, and feelings of indebtedness to the many persons who had so thoughtfully planned and successfully carried out the generous hospitality of the dedication of the new Louvain Library.

An honorary doctorate degree from the University of Louvain was conferred upon Doctor Edward Dean Adams and he was made Commander of the Order of the Crown by the Belgian Government. Upon Mr. A. D. Flinn, Secretary of the Commission, was conferred the degree of Honorary Doctor of Science.

Doctor George F. Swain of Harvard Receives Lamme Medal

The first award of the Benjamin G. Lamme gold medal "for accomplishment in technical teaching or actual advancement of the art of technical training" has been made to Dr. George Fillmore Swain of Harvard.

The medal is awarded by the Society for the Promotion of Engineering Education.

Dr. Swain has attained distinction as a thorough and practical engineer, an inspiring teacher and an authoritative writer. He received his technical education at the Massachusetts Institute of Technology and the Royal Polytechnic School of Berlin. Honorary degrees have been granted to him by the New York University and the University of California.

In 1887 Dr. Swain started his teaching work at the Massachusetts Institute of Technology. Since 1909 he has been a distinguished member of the faculty of the Harvard Engineering School.

Dr. Swain has served as a Consulting Engineer for the Massachusetts Railroad Commission and has been associated with a number of engineering enterprises mainly in the field of transportation. His achievements have stood the test of time and his published works provide a means for extending his influence to the future.

Special Diesel Engine Course at Brooklyn Polytechnic Institute

In order to meet the rapidly increasing demand for information concerning the principles and operation of the diesel engine, the Polytechnic Institute of Brooklyn has offered a special evening course, separate from the regular undergraduate work and designed solely for those interested in oil engines regardless of previous education. This course includes 22 lectures to be given every Tuesday evening at 7:30 o'clock, during the winter, beginning the last Tuesday in September. It was conceived first in 1923 and since that time some 400 men among marine superintendents and operators, steam engine operators, oil chemists, railway men, insurance men and others have availed themselves of it. They are trained in the building, operating, designing and selling of oil engines, the lectures being supplemented by class-room exercises and laboratory work, where several types of oil engines are available for demonstration and testing purposes. Enrolment is every Monday evening.

A. I. E. E. Section Activities

PAST SECTION MEETINGS

Atlanta

Transatlantic Telephony, by Lloyd Espenschied, American Telephone & Telegraph Co. June 15. Attendance 20.

Cincinnati

Annual Meeting. Talk by Daniel Cook, Prof. of Free-hand Sketching, University of Cincinnati. Dinner preceded the meeting. The following officers were elected: Chairman, R. C. Fryer; Secretary-Treasurer, L. O. Dorfman. June 14. Attendance 46.

Columbus

Household Electrical Engineering, by G. W. Alder, Consulting Engr., Good Housekeeping Institute. Annual Dinner Meeting. The following officers were elected: Chairman, W. E. Metzger; Vice-Chairman, J. A. Montgomery; Secretary, R. A. Brown; Assistant Secretary, W. C. Johnson. May 25. Attendance 80.

Indianapolis-Lafayette

Rebuilding the Broadcast Structure, by Ralph G. Langley, Crosley Radio Corp. Illustrated with slides. May 25. Attendance 46.

Lynn

Inspection trip to Edgar Station of the Edison Electric Illuminating Company at Weymouth, Mass. June 9. Attendance 30.

Mexico

Recent Developments on Steam Power Plants, by J. K. Jennings, Metropolitan Vickers Co. Illustrated with slides. July 3. Attendance 25.

Milwaukee

The Milwaukee Sewage-Disposal Plant, by Robert Cramer, Chief Engr., and James Brower, Master Mechanic. The following officers were elected: Chairman, E. R. Stoekle; Secretary-Treasurer, R. R. Knoerr. June 20. Attendance 65.

Philadelphia

Engineering Education, by W. E. Wickenden, Director of Investigation, Society for the Promotion of Engineering Education. A dinner preceded the meeting. January 9. Attendance 60.

Toledo

Dinner Meeting. The following officers were elected: Chairman, W. T. Lowery; Vice-Chairman, E. B. Featherstone; Secretary-Treasurer, Max Neubar. Short talks were given by C. L. Proctor, W. E. Richards. J. F. O'Connor, P. R. Knapp and G. W. McIver. June 19. Attendance 25.

Vancouver

Annual Meeting. Dinner preceded the meeting. The following officers were elected: Chairman, C. W. Colvin; Secretary, J. Teasdale. June 5. Attendance 38.

Worcester

Inspection of Hydraulic Laboratory of the Worcester Polytechnic Institute at Chaffins. Prof. Allen described the laboratory equipment. C. E. Anderson, New England Power Co., gave an illustrated talk on the Bellows Falls Plant. June 28. Attendance 55.

A. I. E. E. Student Activities

BRANCH MEETINGS

Lewis Institute

Business Meeting. Election of officers. June 12. Attendance 19.

University of New Hampshire

Transportation, by L. E. Lynde, '20, Mgr., Transportation Division, Westinghouse Electric & Mfg. Co., Boston. April 28. Attendance 49.

Economics of Railway Electrification, by L. E. Boodey; supplemented by R. M. Knight, and

Harnessing Nature's Electricity, by A. L. Neal; supplemented by M. S. Hodgdon. May 19. Attendance 33.

Résumés of these by seniors: *Electric Elevators*, by F. W. Drew; *Lightning*, by R. W. Folsom, and

Operation of Single-Phase Induction Motors, by I. N. Gove. Motion picture, entitled "Making Mazda Lamps," was shown. May 26. Attendance 31.

College of the City of New York

Theater party. June 19. Attendance 13.

Northeastern University

The Cathode Ray Oscillograph, by Milton W. Jepson, student. May 31. Attendance 41.

PERSONAL MENTION

George W. Swenson, Assistant Professor of Electrical Engineering, University of Minnesota, has resigned to accept the position of Professor of Electrical Engineering at the Michigan College of Mines and Technology, Houghton, Michigan. He will be head of this department, which has just been established. Professor Swenson had been a member of the Electrical Engineering Department at the University of Minnesota since 1918, in charge of communication courses and laboratories. He will assume his new duties on or about September 1.

W. C. Goodwin, formerly Section Engineer of the Control Engineering Department, of the Westinghouse Electric & Manufacturing Company has been appointed manager of its Renewal Parts Engineering Department. In August, 1926, Mr. Goodwin went to England as liaison engineer for the Westinghouse Company with European companies. He represented the Westinghouse Engineering Department in Europe for almost two years spending time in England, France, Italy, Norway, Germany and Czecho-Slovakia. He is an associate member of the Institute and was secretary of the Pittsburgh Section.

Carl A. Heinze, for 21 years engaged in electrical engineering work with Los Angeles Acqueduct and Municipal hydropower enterprises, and for the past twelve years distribution engineer for the municipal electric system, has been appointed Assistant "Chief Electrical Engineer and General Manager" of that City's Bureau of Power and Light. Heinze's appointment as the second ranking engineering official of the Municipal Power Bureau was made by the Board of Water and Power Commissioners on the recommendation of E. F. Scattergood, Chief Electrical Engineer and General Manager of the Bureau. The appointment became effective July 1st.

Obituary

William Esty, head of the Department of Electrical Engineering, Lehigh University and Fellow of the Institute since 1913, died suddenly at Pocono Lake preserve, Bethlehem, Pa. July 6, while enroute to the summer camp of Doctor William Pomp Walker, head surgeon of St. Luke's hospital of this city. His car stalled on a steep hill and Professor Esty started to walk to a garage about 100 yards distant. He collapsed and had died by the time assistance reached him.

Professor Esty was born at Amherst, Mass. July 9, 1868, obtaining his degree of A. B. at Amherst College in 1889 and an M. A. degree in 1893. Subsequent to his graduation from Amherst in 1889, he entered the Massachusetts Institute of Technology and graduated with a degree of S. B. in E. E. in 1893. He then entered the factory of the Thomson-Houston Electric Company at Lynn, Mass. and there spent a year in completing a so-called "expert course" given there. Here he was also employed in the Calculating Department, carrying out special investigations in railway and motor engineering. In the Fall of 1893 he accepted a position as Instructor in Electrical Engineering at the University of Illinois and in 1895 was promoted to an assistant professorship. In 1898 he was again promoted to Associate Professor in Electrical Engineering and for one year was in responsible charge of the department. In 1901 his call to Lehigh University came and he accepted, becoming Assistant Professor in Electrical Engineering. His work was exclusively with the upper classes, including juniors, seniors and post-graduates, in sole charge of many theses investigations. The results of some of these investigations, together with other work led to the publication of Professor Esty's article entitled "Some Experimental Data on the Design of Electromagnets" and published in *The Technograph*, an annual publication of the Engineering Society of the University of Illinois. It was also published in the *Electrical World*, Vol. XXV., p. 565. Some other contributions of Professor Esty's to technical literature are "A Descriptive Index of Some Typical Electric Light and Power Central Stations and Isolated Plants," "Data on Electric Car Heaters," "Effects of Temperature on Insulation Materials." "L'Eclairage Electrique," *Electrican*, "London and Electrical Engineering Courses at College and the Education of the Electrical Engineer," as published in the A. I. E. E. Transactions, Vol. XIX, p. 1155. These are his shorter papers; there were also several books in coauthorship with Professor Franklin, all considered authorities on their several subjects, and one, A-C. Machinery published in 1911 reaching a new edition in 1920. Professor Esty was a member of the Society for the Promotion of Engineering Education and was first elected to membership in the Institute in 1895.

Henry Herbert Lloyd, who was elected to membership in the Institute in 1894 and late president of the Electric Storage Battery Company, Philadelphia, Pa., died July 3 after a long illness. Born in Wales, July 2, 1862, Mr. Lloyd passed Cambridge local examinations for students not members of the University. He came to this country to take graduate chemistry work and forty years ago took charge of the Welsbach Light Company; later assuming a similar position with the United Gas Improvement Company. His history in the storage battery field covers a period of some twenty years. Mr. Lloyd was a Fellow of the English Chemical Society, a member of the Racquet Club, Radnor Hunt, Philadelphia Country and Locust clubs.

William Pestell, vice-president of the Riley Stoker Corporation and Fellow of the Institute (1913) was suddenly striken on

July 10 while on a business trip and died in his Pullman berth just as the train was entering New Orleans. Mr. Pestell was a native of Oakham, Rutland County, England, but had been a resident of Worcester, Mass. for almost two decades. His early technical education was acquired through home study and lecture courses, and in 1889 he joined the New England Electric Company of Boston, agents for Sprague Motors, his work being in the field of installation general repair and winding. The year 1891-1892 was spent with Naumkeag St. R. R. Company, Salem and the following seven years, as assistant electrical engineer for the Lynn and Boston St. Railway Company. His next connection was with the Worcester Consolidated St. Railway Company, as superintendent of motive power and machinery.

For several years he was connected with the Allis-Chalmers Company of Boston and the J. G. White Engineering Company of New York. He was a member of the American Society of Mechanical Engineers, the Engineers' Club of Boston, the Western Society of Engineers in Cleveland, the American Railway Association and the New England Railway Club. At the time of his death, Mr. Pestell was on his way to New Orleans to consult with the officials of a local engineering firm.

Benjamin Needham Jones, general works engineer for the Otis Elevator Company of New York, treasurer of the National Metals Trades Association and Member of the Institute since 1903, died Wednesday, July 4, at his home, Glen Ridge, New Jersey. He was born at Somerville, N. J., April 1, 1871 and after a private school education, spent five years at Stevens School, Hoboken and one year at Stevens Institute. In 1890 he was chosen assistant to the superintendent of construction at the power house erected by the Edison General Electric Company Milwaukee; in 1891 took charge of the power plant at Princess Anne Hotel, Virginia Beach, Va. and in 1892 designed and superintended the construction of a new 150-hp. plant to replace the old one at this hotel. Mr. Jones spent some time with the Sprague Electric Elevator Company in New York City and was sent by this Company to Chicago to make company installtions there. He continued with the company until the Sprague Electric Company was formed and was then transferred to the Engineering Department to assist the superintendent of construction. In this connection, he spent several months with Mr. F. J. Sprague, equipping the South Side Elevated R. R. in Chicago with the "multiple unit system" of train control. In 1898 he returned to New York to do general company work until 1900, when he resigned to accept a position as electrical engineer of the Marine Engine & Machine Company, Harrison, N. J. Mr. Jones was a member of The American Society of Mechanical Engineers and the American Society of Automotive Engineers.

Edwin Britton Katte, chief engineer of electric traction on the New York Central Railroad for the last 22 years, passed away at his home, Lane's End, Irvington-on-Hudson, July 20.

Mr. Katte came of an engineering family, his father, Col. Walter Katte being for many years chief engineer of the New York Central. His mother was Elizabeth Britton, daughter of the former Mayor of St. Louis. The family dated back to Revolutionary days in Virginia.

Mr. Katte was born in St. Louis, but received his general education in the private schools of New York City. Mr. Katte received his degree in mechanical engineering from Cornell University—Sibley College—in 1893. The following year he received the graduate degree of Master Mechanical Engineer.

For one year he was in the Erecting and Testing shops of Henry R. Worthington, Brooklyn, remaining there for two years gaining much experience in the testing of electric pumps and later, large water works engines. He was next with the Park Avenue Improvement Commission for two years as assistant engineer in charge of superstructure. His career as a railroad man then began and for four years he was with the New York Central and Hudson River Railroad Company as mechanical engineer in charge of heat, light and power stations as well as fuel and water supply. This is the work in which he continued until his appointment as electrical engineer in charge of electric traction work. Mr. Katte was a former vice-president of The American Society of Mechanical Engineers, former president of the New York Electrical Society, a member of the American Railway Association engineering Association and a Fellow of the Institute since 1912. He was recognized as one of the most important engineers in the American development of electric transportation on steam railroads. He was a member of Kappa Alpha, the Century Club, the Railway Transportation Club, the New York Club and the University Club of New York.

Arthur L. Freyer, who for the last 10 years has served the Northern Indiana Public Service as distribution engineer died late in June in St. Margaret's Hospital, Hammond, Ind. He was born in Michigan City 46 years ago and after graduating from high school attended the Valparaiso University. Completing the advanced electrical engineering course, he assumed the charge of the electric light and water plant at Walkerton, where he served for 12 years. For the next two years he was superintendent of the Plymouth Power and Light Company before coming to Hammond, to enter the engineering department of the Northern Indiana Gas & Electric Company. Mr. Freyer became an Associate of the Institute in 1922.

Robert I. Todd, president of the Indianapolis Street Railway Company and former president of the American Electric Railway Association, died about midnight of July 13, of heart disease. Mr. Todd joined the Institute in 1904 as an Associate and was later elected a Member. He was born at Lakewood N. J., November 29, 1869, was a graduate of Johns Hopkins University's Electrical Engineering course from which he received his E. E. degree in 1893, and immediately thereafter went to work for the City and Suburban Railway Company of Washington, D. C. as superintendent and electrical engineer. During the next thirteen years he served with various engineering firms, most of them traction companies, including The Rhode Island Company, Providence, R. I. as General Manager and The Cincinnati Traction Company as second vice-president and General Manager, General Master mechanic of the Consolidated Traction Company of Pittsburgh, engineer of the American Air Power Company, New York, N. Y.

For the past twelve years he had concentrated his activities in Indianapolis, where he was president of the Terre Haute, Indianapolis and Eastern Traction Company, the Broad Ripple Traction Company, Terre Haute Traction and Light Company, Indianapolis and Northwestern Traction Company, Indianapolis, and Eastern Railway Company, Indianapolis and Greenfield Rapid Transit Company, the Arcade Realty Company, United Tractions Coal Company, the Indiana Motor Transit Company and a number of additional associate companies.

He served at one time as president of the American Electric Railway Association, of the Central Electric Railway Association and of the American Electric Railway Transportation & Traffic Association. He was a member of the American Institute of Electrical Engineers and was a member of a number of prominent Indianapolis clubs.

He resided at 1329 North New Jersey Street and is survived by a wife, who before her marriage was Miss Charlotte L. Vinal of Middletown, Conn., and one son, Robert W. Todd.

Engineering Societies Library

The Library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES JUNE 1 TO JUNE 30

Unless otherwise specified, books in this list have been presented by the publishers. The Institute does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

Allgemeine Chemische Technologie.

By H. Bausch. Berlin, Walter de Gruyter & Co., 1928. 155 pp., 6 x 4 in., cloth. 1.50 rm.

A popular account of the present status of general chemical technology. Includes acids and alkalies, cements and glass, petroleum coal, dyes, fats and oils, rubber, etc.

Automatic Telephony Simplified.

By C. W. Brown. N. Y., and London, Isaac Pitman & Sons, 1928. 168 pp., illus., diagrs., 7 x 5 in., cloth. $1.75.

The contents of this volume recently appeared as a series of articles in the *Telegraph and Telephone Journal.* The book deals with principles of automatic telephony and gives only a view of the numerous circuits in detail.

Elektrizitätswirtschaft.

By R. Fischer. Berlin, Walter de Gruyter & Co., 1928. 148 pp., 6 x 4 in., illus., diagrs., tables, cloth. 1.50 rm.

On the electricity industry, reviewing the methods of obtaining energy, the demand for electricity and the production and distribution of it. There is a short chapter on rate-making, followed by an account of the electrical industry in Europe and the United States.

The Elements of Hydrology.

By Adolph F. Meyer. 2nd edition. N. Y., John Wiley & Sons, 1928. 522 pp., illus., diagrs., tables, maps, cloth. $5.00.

This book contains chapters on atmosphere, water, precipitation, evaporation and stream flow. This, the second edition, includes about 40 pages of new material, such as rainfall studies by the Miami Conservancy District, and the work by Marston on the area covered by intense rainstorms of short duration. The new evaporation formulas by Horton and Parshall are added and Houk's runoff studies at Dayton are summarized. Vermeule's and the Minnesota runoff formulas are also included.

Estimating Building Costs.

By William Arthur. 3rd edition. N. Y., Scientific Book Corporation, 1928. 233 pp., diagrs., tables, 7 x 5 in., cloth. $2.00.

This book is especially written for building tradesmen, contractors, material men, and technical students. It is intended as a guide in the construction of small buildings, and has an introduction to the "New Building Estimators' Handbook."

Five Hundred Sheet Steel Products and Who Make Them.

Compiled by Sheet Steel Trade Extension Committee. Pittsburgh, Pa., 1927. 445 pp., 11 x 8 in., boards. $3.00.

This book gives a brief history of iron and steel, lists of manufacturers of sheet steel, alphabetical lists of fabricators and sheet steel products with the names of manufacturers. The compilers of this volume have tried to facilitate the work of buyer and seller by making it as easy as possible for the former to quickly locate the latter.

Hochfrequenzmesstechnik Ihre wissenschaftlichen und praktischen Grundlagen.

By August Hund. 2nd ed. Berlin, Julius Springer, 1928. 526 pp., 9 x 6 in., cloth. 39 rm.

The extraordinarily rapid development of the subject of high frequency has led to a second enlarged edition of this book.

Long derivations of formulas have been placed at the end of the book, and explanations have been printed on the diagrams so that they can be studied without the text. Material has been added on voltage measurement using tubes, also on magnetic or electric fields in space. The theory of the long horizontal antenna has been expanded and the subjects of frequency measurement, the use of the piezoelectric generator and resonator for frequency standards are discussed.

Industrial Management.

By Richard H. Lansburgh. 2nd edition. N. Y., John Wiley & Sons, 1928. 509 pp., 9 x 6 in., illus., charts, cloth. $4.50.

This book has been revised in accordance with many changes in management technique and management emphasis. The subject of mechanization has been stressed and the chapters on specialized machinery, material handling, and management control through costs, have been expanded. Chapters on the effects of quantity production and planning, operating the budget and the relationship of management and organization labor have been added.

Keystone Coal Mining Catalog, 1927. N. Y., McGraw-Hill Catalog and Directory Company, Inc., 1927. 842 pp., illus., tables. 11 x 8 in., cloth. $15.00.

One of the features of this edition is the bringing together of the Engineering Data and its arrangement as a separate and special section in the back of the book. This, together with the elimination of textbook treatises and data not pertinent to purchasing problems, has reduced the bulb of the catalog and made it more convenient for reference.

The manufacturers' descriptive information on their products is arranged and indexed so that details on particular supplies and equipment can be found quickly.

Mechanical Engineering, A Text-Book for a Short Course.

By W. A. Mitchell. N. Y., John Wiley & Sons, 1928. 402 pp., diagrs., 9 x 6 in., cloth. $4.00.

This book has been prepared for the cadets of the United States Military Academy. It is intended to teach the cadet enough of the principles of mechanical engineering so that he may in the future understand the practical engineering requirements of his profession.

Mechanochemistry and the Colloid Mill, Including the Practical Applications of Fine Dispersion.

By Pierce M. Travis. N. Y., Chemical Catalog Co., 1928. 181 pp., 9 x 6 in., illus., diagrs., cloth. $4.00.

By mechanochemistry the author means the new science of mechanical dispersion, involving the principles of physical chemistry. He selects this term because it involves dispersion or deflocculation by mechanical means rather than by chemical. In visualizing the problem and working with some degree of intelligence in trying to solve some of the mysteries of the so-called colloidal state of matter, one may proceed by a sort of trial and error method. The author hopes that this book may eliminate the guess method in such operations.

Outlines of Public Utility Economics.

By Martin G. Glaeser. N. Y., Macmillan Company, 1927. 847 pp., diagrs., charts, tables. 9 x 6 in., cloth. $4.25.

This book is the outgrowth of seven years of teaching of the subject of public utilities in university classes. It is intended to present the subject in a way which will introduce the reader to the field in its entirety, because of the great degree of interaction between conditions in the several public service industries. A selected bibliography has been included, as well as questions for review, and problems.

Photochemical Processes.

By George B. Kistiakowsky. N. Y., Chemical Catalog Company, 1928. 270 pp., 9 x 6 in., cloth. $5.50.

In this volume the author has attempted an analysis from the standpoint of quantum theory to those photochemical reactions of which the study has been sufficiently detailed so that some definite conclusions concerning the kinetics of the process can be reached. The chapter headings are: Concept of Light Quanta and Photochemical Kinetics; The Equivalence Law; Chain Reactions; Photosensitisation; Catalysis and Inhibition; and Frequency of Radiation, Temperature and the Rate of Photochemical Reactions.

Practical Sheet Metal Duct Construction.

By William Neubecker. 4th ed. N. Y., Sheet Metal Publication Co., 1928. 225 pp., illus., diagrs., 8 x 6 in., cloth. $3.00.

This book relates to the construction and erection of heating and ventilating ducts, registers and dampers. It illustrates the method of calculating areas of pipes and ducts, and the construction of a large ventilator. It also describes the design and layout of duct fittings and the method of taking off quantities of material in duct work.

Principles of Mechanism.

By F. Dyson. N. Y., Oxford University Press, American Branch, 1928. 296 pp., diagrs., 9 x 6 in., cloth. $4.25.

The author has written this book for students studying the fundamental principles of moving parts of machines. No attempt has been made to apply the principles involved to the design of actual machines. The text contains examples with their solutions, and problems have been placed at the end of each chapter.

Storage Batteries, Theory, Manufacture, Care and Application.

By Morton Arendt. N. Y., D. Van Nostrand Company, 1928. 285 pp., illus., diagrs., 9 x 6 in., cloth. $4.50.

This book is a development of lectures to engineering students at Columbia University and to officers at the United States Submarine School. It is based on the author's practical experience in battery manufacture and maintenance, which features have been emphasized. Only such theory as is actually necessary to account for reactions and cell characteristics has been considered. The influence of plate construction, purity of material and electrolytic diffusions as primarily controlling cell behavior has been given special consideration.

Surveying, Theory and Practise.

By Raymond E. Davies, Francis S. Foote and W. H. Rayner. N. Y., McGraw-Hill Book Co., 1928. 1016 pp., illus., diagrs., tables, 8 x 5 in., cloth. $5.00.

This book is intended for use in surveying classes as ordinarily conducted in engineering schools during the freshman or sophomore year. It has also been the aim of the authors to produce a treatise on the subject of surveying sufficiently comprehensive to be of value to practising engineers and surveyors.

The elementary phases of the theory and practise of surveying have been treated in considerable detail. The more advanced phases of the subject have been discussed, methods used on extensive surveys under a variety of conditions have been described, and the relative advantages of the different methods as affected by field conditions have been considered.

Taschenbuch für Bauingenieure.

Edited by Max Foerster. 2 vols. 5th edition. Berlin, Julius Springer, 1928. Vol. 1, 1115 pp., vol. 2, 1422 pp., 8 x 5 in., diagrs., tables, cloth. 42.50 rm.

The first volume of this handbook takes up the theoretical and fundamental subjects, mathematics, mechanics, etc., surveying, machines used on construction, and finally, short sections on telephony, telegraphy and devices for safety in railway operation.

The second volume is on construction, including wood and masonry, iron bridges, water engineering (river and sea works, canals, dams and water power) water supply and drainage, roads, earthwork, tunnels, and railway construction.

Technical Drawing, A Manual for Evening Classes and Junior Technical Schools.

By George Edwin Draycott. N. Y., Oxford University Press, American Branch, 1927. 232 pp., illus., diagrs., 7 x 5 in., cloth. $2.00.

This book is intended to illustrate a method of instruction in technical drawing for evening classes and junior technical schools. In order to avoid the tendency to turn the subject into engineering drawing on one hand or building on the other, the subject is based upon exercises in plane and descriptive geometry into which simple objects other than the required geometrical solids may be introduced even in the earlier stages.

A Text Book of Telegraphy, Theoretical and Practical.

By A. E. Stone. London, Macmillan and Co., 1928. 455 pp., diagrs., 9 x 6 in., cloth. 20s.

This book is intended to meet the requirements of those students who are preparing for examinations. The author has tried to make the descriptions of apparatus and systems complete without confusing the mind of the reader with intricate diagrams. Special attention has been given to multiplex systems and type-printing telegraphs; and the underlying principles of submarine telegraphy and radio telegraphy are taken up.

Two Essays in Early Locomotive History.

By C. F. Dendy Marshall. London, Locomotive Publishing Co., 1928. 120 pp., illus., diagrs. 11 x 8 in., cloth. 12/6.

This book contains the principal facts, so far as they can be ascertained by the author on the first hundred locomotives that were actually built. The work of each builder is taken up separately. The question of British locomotives in North America is discussed as well as engines supplied to Canada. About 120 engines were supplied to railways in the United States, but after 1836 the demand for British engines ceased as the railways built their own.

Versuche mit Allseitig Aufliegenden Rechteckigen Eisenbetonplatten unter Gleichmässig Verteilter Belastung. v. 2.

By Otto Graf. Berlin, Wilhelm Ernst & Sohn, 1926. (Deutscher Ausschuss für Eisenbeton, heft 56.) 32 pp., illus., diagrs., tables, 11 x 7 in., paper. 6,90 rm.

Presents in detail the results of an extended series of tests carried out in the materials laboratory of the Stuttgart Technical High School during the years 1921-1925, as a continuation of those published in 1915 in this same series of reports.

WECHSELSTROM-KOMMUTATORMASCHINEN.

By Karl Baudisch. Berlin, Walter de Gruyter & Co., 1928. 104 pp., illus., diagrs., 6 x 4 in., cloth. 1.50 rm.

Takes up the method of operation and the application of commutator machines, the commutator armature and its properties, and single and polyphase commutator motors.

YEAR BOOK ON COAL MINE MECHANIZATION.

Compiled by G. B. Southward. Wash., American Mining Congress, 1928. 273 pp., illus., diagrs., 9 x 6 in., paper. $3.00.

This Year Book is the result of several years of constant effort on the part of the National Standardization Division of the American Mining Congress, through the Mining and Loading Section, to promote the introduction of mechanical methods of production. It contains history of mechanization; statistics on mechanical loading; mechanized mining in various states; the mechanization survey and reports on it, types of mechanization equipment and a bibliography on coal mine mechanization.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—31 West 39th St., New York, N. Y.,—W. V. Brown, Manager.
1216 Engineering Bldg., 205 W. Wacker Drive, Chicago, Ill., A. K. Krauser, Manager.
57 Post St., San Francisco, Calif., N. D. Cook, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 31 WEST 39th Street, New York City,*** *and should be received prior to the 15th day of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by contributions made within thirty days after placement, on the basis of one and one-half per cent of the first year's salary; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

ELECTRICAL-MECHANICAL ENGINEER with experience in the manufacture of high-tension underground and overhead equipment; oil switch experience particularly desirable; good knowledge of modern shop practise and ability to coordinate designing and manufacturing essential. Salary $4800 a year. Apply by letter. Location, Middlewest. X-5375-C

JUNIOR ENGINEER, recent college graduate, 23-28, with or without experience in telephone engineering or associated work. Experience not essential as a six months' training program is arranged. Must have initiative and potential supervisory ability. Salary $32-$40 a week. Location, New York. Apply by letter. X-5461.

MEN AVAILABLE

ELECTRICAL ENGINEER, 31, graduate, married. Six years high-tension, substation transmission line layout, design, material; two years with architect, complete plans, specifications, engineering, wiring for light, power, signals; for theaters, office buildings, hotels, apartments; one year full charge electrical installations big buildings for contractor. Qualify as estimating engineer anywhere in United States. B-4217.

TECHNICAL TRAINING. Ten years' electrical experience. Past six years with large public utility. Line department wiring inspection, meter department. At present in charge of inspection and meter department can deal with customers; direct men. Speaks Spanish. Location, immaterial; foreign preferred. C-3057.

GRADUATE, 21, single, who has obtained a B. S. in Electrical Engineering desires a position with a company doing engineering work, preferably electrical. Ready to do anything to get ahead. Location, New England or New York. C-4752.

GRADUATE ELECTRICAL ENGINEER, 1928, desires position with public utility or industrial concern. A position with opportunity for advancement desired. Location preferred, East. C-4528.

ASSISTANT PROFESSOR OF ELECTRICAL ENGINEERING, 34, married, A. B. and A. M. degrees; 15 years college and university teaching; 5 summers public utility testing and transmission engineering; desires position as head of department or professor of Electrical Engineering in first class engineering school. Location preferred, Midwest. C-4746.

1928 GRADUATE IN E. E., of the Pennsylvania State College, desires a position with a public utility or manufacturing company. Has had one summer's experience in the general sales department of a power company. Took special courses in electric illumination, electric railways and radio. Location, immaterial. C-4760.

SUPERVISOR OF ELECTRICAL CONSTRUCTION, 42, engaged at present with City of Philadelphia, on construction of Broad Street Subway in above capacity; work nearing completion. Available September 1, 1928. B-9571.

ELECTRO-MECHANICAL ENGINEER, graduate, 31, single; exceptionally good on superior mathematics, experienced on all phases of transmission line layout and transmission tower design. Also experience on design of power houses, switch, houses, substations. Some mechanical practise. Moderate salary. Location, immaterial. C-401.

ELECTRICAL ENGINEER, 32, married; 1½ years General Electric test; 1½ years construction; 6 years design and construction central and substations. Can take charge of construction or design. Location, vicinity of New York City. Available immediately. B-8231.

GRADUATE ELECTRICAL ENGINEER, desires position with public utility or industrial firm. Two years electrical test course. Three years assistant to Electrical Engineer of industrial company. Five years electric design of power plants and substations. Five years gas experience on by product coke and water gas plant. B-8379.

ELECTRICAL ENGINEER, 31, married. College graduate with two years' construction and maintenance experience and seven years research, development and production management. Able to organize and produce results. Location and salary secondary to opportunity. C-4652.

RECENT GRADUATE, A. B. in E. E., 22, single, desires position with a university, public utility or industrial concern doing test or research work. Four summer vacations experience with power company and nine months' experience on Westinghouse E. & M. Co. test floor. C-4729.

MECHANICAL AND ELECTRICAL ENGINEER, 31, married. Eight years' experience on drafting board in all branches of mechanical work. Eight years' experience designing and building small electrical instruments. Broad knowledge of modern manufacturing methods. Some executive ability. Very good creative ability. Location, within commuting distance of Providence, R. I. C-4745.

ELECTRICAL ENGINEER, single, 28. Graduate, practical training and 6 years' experience as plant engineer and designer: generating stations, substations, industrial substations. Listing estimating, investigating, designing, etc. for manufacturing concern, public utility, construction company, consulting engineer and industrial concerns. Speaks French and German. Available on short notice. Location, East or abroad. C-4758.

ELECTRICAL ENGINEER, 23, single, E. E. degree, 1926, desires position in the commercial

department of a public utility or industrial firm. Sixteen months on test with the General Electric Company and now employed in training course of a public utility. Location, East, South or Middlewest. C-4810.

ELECTRICAL ENGINEER, MANUFACTURING EXECUTIVE. American born, Christian. Technical graduate experienced in development, design and manufacture of instruments and small electrical apparatus. Expert in standardizing such products for commercial manufacture. Developing and planning new methods and processes, inspections and tests. Experienced executive, thoroughly familiar with modern factory organizations, selection and supervision of personnel. B-2721.

GRADUATE ELECTRICAL ENGINEER. Especially acquainted with the selection and application of electrical equipment for power houses, substations, industrial plants, relay and meter practise, wiring diagrams, switchboard design. With operating experience. Desires position with a public utility or industrial concern. Location preferred, Middlewest or East. C-4696.

ELECTRICAL ENGINEER, with 20 years' practical experience in designing electrical machines and apparatus, laying out transmission lines, substations; having had charge of research; sound theoretical knowledge in general engineering problems, desires responsible permanent position, preferably Pittsburgh or East. Speaks German and French, would take representation abroad. C-693.

LICENSED PROFESSIONAL ELECTRICAL ENGINEER, 37, married. Sixteen years' broad experience in electrical design, construction and operation of power stations, sub-stations, lighting and power for industrial buildings; office and experiences in appraisal work; desires new connection with an engineering organization or public utility. B-5393.

GRADUATE ELECTRICAL ENGINEER, B. S. in E. E., 1924; 27, married, no children. One year General Electric Test; two years office engineer in apparatus sales; six months electrical drafting; six months teaching in a recognized university. Available one month's notice. Desires teaching or sales position. Pacific coast preferred. C-4740.

ELECTRICAL ENGINEER, 30, married. Honor graduate in E. E. Two years General Electric Test. Two years design a-c. motors and generators. Division engineer on electric railroad. Complete charge of all maintenance and construction work. Estimates and construction of new substations, sidings, etc. C-3080.

ELECTRICAL ENGINEER, 29, married. Four years with Western Electric Company, switchboard wiring department; three years high-tension substation and power plant construction experience, specializing in metallic telephone and carrier current telephone for transmission system. Can take complete charge of installation. Excellent references. C-4831.

ELECTRICAL ENGINEERING GRADUATE, 27, single, good health, desires position with operating or public utilities company. Four years' experience in electrical service and repair work and five years' business experience devoted largely to selling. Available immediately. Southern location preferred but not essential. C-4828.

ELECTRICAL ENGINEER. One year post graduate work and 12 years' experience in design, construction, research and development with deep understanding of fundamentals of electrical, electromagnetic and electromechanical phenomena, with many inventions to his credit, wishes connection as director, of industrial research laboratory. Especially fitted for organizing new laboratory. Salary, $5500. B-4975.

GRADUATE ELECTRICAL AND MECHANICAL ENGINEER. 18 years' experience in electric substation construction and operation; in design, construction, operation and maintenance of electric locomotives, cars, shops, switchboards, electrical and mechanical equipment. Broad factory and engineering experience with large manufacturer; A-1 mechanic. Positions held: assistant master mechanic, engineer of equipment, construction foreman, engineering inspector. C-4519.

GRADUATE ELECTRICAL ENGINEER, 31, single, with four years' experience on motor repairing, wiring and mechanical work; two years electrical construction and maintenance, desires connection with manufacturing concern where a constructive mind and practical knowledge are needed. Location, New York City and vicinity. C-4837.

ELECTRICAL ENGINEER, 30, married, desires work on hydroelectric construction or operation. Experience: two years hydro, one and one-half years steam plant operation, one and one-half years substation construction, four years high-head hydroelectric construction. Now chief electrician hydroelectric construction. Expert switch-board wireman. Location immaterial; Japan or India preferred. C-4482.

ELECTRICAL ENGINEER, 35, married. Seven years sales specialist, excellent knowledge of use and costs pole line construction material. Also four years' electrical experience in connection with industrial plants and central stations. Wide acquaintance with central station field. Has knowledge of purchasing. Location, East, South or Middlewest. B-1196.

ELECTRICAL ENGINEER, Canadian, McGill graduate. Good balance of design, construction, operating engineering on hydroelectric stations, substations. Thorough understanding of engineering principles and their application. Have supervised design, research on various types substations. Six years' experience with American, Canadian organizations, including electrical laboratory, electrical design, inspection; checker; assistant engineer of design. Also independent business experience. C-4668.

ELECTRICAL ENGINEERING GRADUATE, 1928, 23, single, would like position as assistant to chief engineer of manufacturing concern or in the research test field. Good personality, reliable and industrious. C-4829.

EXECUTIVE-ENGINEER, American, technical graduate with twenty years' experience on design and construction of transmission lines up to 132-kv. distribution systems, rural lines, generating stations, substations up to 132-kv. buildings, valuations, tax reports, testing and some operating experience. Capable of organizing and carrying on big work. Location, United States. C-4852.

MEMBERSHIP—Applications, Elections, Transfers, Etc.

APPLICATIONS FOR TRANSFER

To Grade of Fellow

LAWS, FRANK A., Professor of Electrical Measurements, Mass. Inst. of Tech., Cambridge, Mass.

To Grade of Member

BALLEW, WALTER W., Branch Manager Westinghouse Elec. & Mfg. Co., Atlanta, Ga.

BLOSS, ERNEST K., Asst. Elec. Engr., Boston & Maine Railroad, No. Billerica, Mass.

CADWALLADER, JAMES A., Engineer of Transmission and Outside Plant, Bell Telephone Co. of Pa., Pittsburgh, Pa.

CLARK, JAMES, Jr., President, James Clark Jr. Electric Co., Louisville, Ky.

CONDON, E. J., Jr., Consulting Engineer, 231 So. La Salle St., Chicago, Ill.

DEMEY, CHARLES F., Rate Engineer, Central Hudson Gas & Elec. Corp., Poughkeepsie, N. Y.

DINGLEDINE, RALPH K., Engineer, Tennessee Inspection Bureau, Nashville, Tenn.

DOOLEY, DANIEL R., Engineer, Automatic Elec. Co. Ltd., Tokyo, Japan.

DORFMAN, L. O., Manager Engg. Division, Westinghouse Elec. & Mfg. Co., Cincinnati, Ohio.

ELLIS, GOULD, Supt. of System Operation, Appalachian Electric Power Co., Charleston, W. Va.

FARNELL, WILLIAM C. F., Member of Technical Staff, Bell Telephone Labs., New York, N. Y.

FISHER, ALLEN H., Asst. General Mgr., The Guanajuato Power & Elec. Co., Guanajuato, Gto., Mexico.

GRAHAM, FRANK H., Telephone Engineer, Bell Telephone Labs., New York, N. Y.

GREEN, A. BARNETT, Engineering Editor and Writer, 1328 Broadway, New York, N. Y.

HALE, ROBERT S., Supt. Special Research Edison Elec. Ill. Co., Boston, Mass.

HOOKE, ROBERT G., Engineer, Elec. Distribution Dept., Public Service Elec. & Gas Co., Newark, N. J.

HUBBARD, RALPH B., Technical Asst. to, Supt., Public Service Co. of Colorado, Boulder, Colorado.

KEENER, CHARLES A., Associate in Elec. Engg., University of Illinois, Urbana, Ill.

LAWTON, ROBERT B., Supt. Big Creek Division, So. Calif. Edison Co., Big Creek, Calif.

LEAVITT, LOUIS S., Managing Editor, Electric Light and Power Magazine, Chicago, Ill.

PERRY, DONALD B., Engineer, American Tel. & Tel. Co., New York, N. Y.

PLANK, HEBER E., Manager, General Elec. Co., Seattle, Wash.

POLK, J. LANE, Jr., Asst. Transmission Line Engineer, Penn. Power & Light Co., Allentown, Pa.

PRESTON, RAY W. Estimating Engineer, Big Creek Project, So. Calif, Edison Co., Big Creek, Calif.

ROBINSON, LYLE B., Transformer Specialist, General Elec. Co., Seattle, Wash.

SEELYE, HAROLD P., Engineer, Detroit Edison Co., Detroit, Michigan.

SIEWERT, H. P., Meter Engr., Public Service Co. of No. Ill., Chicago, Ill.

STEMMONS, BEVERLY L., Electrical Engineer, Duke Power Co., Charlotte, N. C.

STEVENS, HENRY R., Consulting Engineer, 625 Liggett Bldg., Seattle, Wash.

STORM, HANS O., Electrical Engineer, Federal Telegraph Co., Palo Alto, Calif.

WOOLEY, WILLIAM C., Elec. Engr., Moloney Elec. Co., St. Louis, Mo.

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a grade higher than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before August 31, 1928.

Almon, C. P., Jr., Alabama Power Co., Birmingham, Ala.
Ayers, B. H., Louisville & Nashville R. R. Co., Louisville, Ky.
Bartlewski, F. J., American Machine & Foundry Co., Brooklyn, N. Y.
Bell, W. L., 4807 Baum Blvd., Pittsburgh, Pa.
Berger, M., 32 Georgia Ave., Long Beach, N. Y. (Applicant for re-election.)
Brick, J. D., Electric Controller & Mfg. Co., New York, N. Y.
Brown, H. W., (Member), General Electric Co., Schenectady, N. Y.
Cave, J. S., (Member), Snook, Martin & Co., Columbus, Ohio
Coyer, E. F., Mountain States Tel. & Tel. Co., Denver, Colo.
Cromwell, P. C., Byllesby Engineering & Management Corp., Pittsburgh, Pa.
Dunkman, E. H., The Triumph Electric Corp., Cathage, Cincinnati, Ohio
Ellerman, L. H., City of Los Angeles, Bureau of Pr. & Lt., Los Angeles, Calif.
Engholm, B. A., The Rola Co., Oakland, Calif.
Gatchell, L. R., Municipal Architects Office Washington, D. C.
Gelin, L., Coverdale & Collpits; I. R. T. Co., New York, N. Y.
Geoghegan, E. D. A., Radio Corp. of America, New York, N. Y.
Ghiselin, W. F., General Electric Co., Houston, Texas
Graeter, R. M., The L. E. Myers Co., Dallas, Texas
Graham, C. H., United Engineers & Constructors' Inc., New York, N. Y.
Griffiths, R. A., 8 Fort Charles Place, New York, N. Y.
Hamilton, R. S., Western Union Telegraph Co., New York, N. Y.
Hill, J. W., Wagner Electric Corp., St. Louis, Mo.
Horn, R. C., Southwestern Bell Tel. Co., Dallas, Texas
Hudson, H. A., Wagner Electric Corp., St. Louis, Mo.
Hume, F., (Member), Southern Bell Tel. & Tel. Co., Atlanta, Ga.
Jacobus, T. C., P. O. Box 750, Schenectady, N. Y.
Jones, H. E., Mountain States Tel. & Tel. Co., Denver, Colo. (Applicant for re-election.)
King, P., 541 West 124th St., New York, N. Y.
Kretz, W. H., Jeffery-Dewitt Insulator Co. & Champion Switch Co., Kenova, West Va.
Leonard, H. G., Winchester Repeating Arms Co., New Haven, Conn.
Loughridge, D. H., United States Steel Corp., New York, N. Y.
Ludorf, L. Z., Pennsylvania Pr. & Lt. Co., Wilkes-Barre, Pa.
Martin, H. G., Westchester Electrical Equipment Co., Yonkers, N. Y.
Martinsen, G. M., Southwestern-Bell Telephone Co., Houston, Texas
McComb, C. W., Commonwealth Edison Co., Chicago, Ill.
McGann, F. A., (Member), Southern Bell Tel. & Tel. Co., Louisville, Ky.
McGillis, S. R., W. R. C. Smith Publishing Co., Atlanta, Ga.
Meier, W. F., Illinois Power & Light Corp., East St. Louis, Ill.
Menconi, L., Westchester Lighting Co., Mt. Vernon, N. Y.
Meyer, A. W., New York Tel. Co., Syracuse, N. Y.
Mower, N. L., The United Electric Lt. & Pr. Co., New York, N. Y.
Moyer, J. A. (Member), Commonwealth of Mass.; Boston, Mass.
Nitschke, C. W., (Member), Mountain States Tel. & Tel. Co., Denver, Colo.
Pierce, N. O., (Member), Mountain States Tel. & Tel. Co., Denver, Colo.
Pitzer, H. W., The L. E. Myers Co., Dallas, Texas
Plank, W. L., General Electric Co., West Philadelphia, Pa.
Powell, M. H., Public Service Co. of Colorado, Denver, Colo.
Reinhard, W. D., (Member), Dwight P. Robinson & Co., New York, N. Y.
Scheel, K. C., Pacific Electric Manufacturing Corp., San Francisco, Calif.
Shepperd, W. B., Century Electric Co., St. Louis, Mo.
Shiepe, E. M., 910 Cortelyou Road, Brooklyn, N. Y.
Shih, C. Y., Mass. Institute of Technology, Cambridge, Mass.
Smith, G. V., (Member), Ohio Brass Co., Mansfield, Ohio
Sproul, H. R., Oliver United Filter Co., Oakland, Calif.
Stark, H. N., Erie Malleable Iron Co., Philadelphia, Pa.
Tesch, E. F., Consumers Power Co., Jackson, Mich.
Warner, R. W., (Member), Kansas City Power & Light Co., Kansas City, Mo.
Wise, E. M., (Member), General Electric Co., Houston, Texas
Total 58.

Foreign

Munshi, J. K., Union Trading Co., Ahmedabad, Bombay, India
Palit, H., Plutus Engineering Co., Benares City, India
Thacker, M. S., Bristol Corp., The Manse, Long Ashton, Bristol, Eng.
Urie, R. J., (Member), Tecnica de Instalaciones Electricas y Mecanicas, Tucuman, Argentina

Total 4.

OFFICERS A. I. E. E. 1928-1929

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A. M. MacCutcheon
A. E. Bettis

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George A. Hamilton

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Ralph W. Pope

LOCAL HONORARY SECRETARIES

T. J. Fleming, Calle B. Mitre 519, Buenos Aires, Argentina, S. A.
H. W. Flashman, Aus. Westinghouse Elec. Co. Ltd., Cathcart House, 11 Castlereagh St., Sydney, N. S. W., Australia.
F. M. Servos, Rio de Janeiro Tramways Light & Power Co., Rio de Janeiro, Brazil, S. A.
Charles le Maistre, 28 Victoria St., London, S. W. 1, England.
A. S. Garfield, 45 Bd. Beausejour, Paris 16 E. France.
F. W. Willis, Tata Power Companies, Bombay House, Bombay, India.
Guido Semenza, 39 Via Monte Napoleone, Milan, Italy.
P. H. Powell, Canterbury College, Christchurch, New Zealand.
Axel F. Enstrom, 24a Grefturegatan, Stockholm, Sweden.
W. Elsdon-Dew, P. O. Box 4563, Johannesburg, Transvaal, Africa.

A. I. E. E. COMMITTEES

The list of committees is omitted from this issue, as new appointments are being made for the administrative year beginning August 1. The new committees will be listed in the September issue.

A. I. E. E. REPRESENTATION

A complete list of A. I. E. E. representatives on various bodies will be published in the September issue.

LIST OF SECTIONS

Akron
Atlanta
Baltimore
Boston
Chicago
Cincinnati
Cleveland
Columbus
Connecticut
Dallas
Denver
Detroit-Ann Arbor
Erie
Fort Wayne
Indianapolis-Lafayette
Ithaca
Kansas City
Lehigh Valley
Los Angeles
Louisville
Lynn
Madison
Mexico
Milwaukee
Minnesota
Nebraska
New York
Niagara Frontier
Oklahoma
Panama
Philadelphia
Pittsburgh
Pittsfield
Portland, Ore.
Providence
Rochester
St. Louis
San Francisco
Saskatchewan
Schenectady
Seattle
Sharon
Southern Virginia
Spokane
Springfield, Mass.
Syracuse
Toledo
Toronto
Urbana
Utah
Vancouver
Washington, D. C.
Worcester
Total 53

Note: Names of new officers will be printed in the September Journal. Names of officers serving to July 31 may be found in the July Journal.

LIST OF BRANCHES

Akron, Municipal University of, Akron, Ohio
Alabama Polytechnic Institute, Auburn, Ala.
Alabama, University of, University, Ala.
Arizona, University of, Tucson, Ariz.
Arkansas, University of, Fayetteville, Ark.
Armour Institute of Technology, 3300 Federal St., Chicago, Ill.
Brooklyn Polytechnic Institute, 99 Livingston St., Brooklyn, N. Y.
Bucknell University, Lewisburg, Pa.
California Institute of Technology, Pasadena, Calif.
California, University of, Berkeley, Calif.
Carnegie Institute of Technology, Pittsburgh, Pa.
Case School of Applied Science, Cleveland, Ohio
Catholic University of America, Washington, D. C.
Cincinnati, University of, Cincinnati, O.
Clarkson College of Technology, Potsdam, N. Y.
Clemson Agricultural College, Clemson College, S. C.
Colorado, University of, Boulder, Colo.
Colorado State Agricultural College, Fort Collins, Colo.
Cooper Union, New York, N. Y.
Denver, University of, Denver, Colo.
Detroit, University of, Detroit, Mich.
Drexel Institute, Philadelphia, Pa.
Duke University, Durham, N. C.
Florida, University of, Gainesville, Fla.
Georgia School of Technology, Atlanta, Ga.
Idaho, University of, Moscow, Idaho
Iowa State College, Ames, Iowa
Iowa, State University of, Iowa City, Iowa
Kansas State College, Manhattan, Kansas
Kansas, University of, Lawrence, Kans.
Kentucky, University of, Lexington, Ky.
Lafayette College, Easton, Pa.
Lehigh University, Bethlehem, Pa.
Lewis Institute, Chicago, Ill.
Louisiana State University, Baton Rouge, La.
Louisville, University of, Louisville, Ky.
Maine, University of, Oronto, Maine
Marquette University, 1200 Sycamore St., Milwaukee, Wis.
Massachusetts Institute of Technology, Cambridge, Mass.
Michigan State College, East Lansing, Mich.
Michigan, University of, Ann Arbor, Mich.
Milwaukee, School of Engineering of, 415 Marshall St., Milwaukee, Wis.
Minnesota, University of, Minneapolis, Minn.
Mississippi Agricultural & Mechanical College, A. &. M. College, Miss.
Missouri School of Mines & Metallurgy, Rolla, Mo.
Missouri, University of, Columbia, Mo.
Montana State College, Bozeman, Mont.
Nebraska, University of, Lincoln, Neb.
Nevada, University of, Reno, Nevada
Newark College of Engineering, 367 High St., Newark, New Jersey
New Hampshire, University of, Durham, N. H.
New York, College of the City of, 139th St. & Convent Ave., New York, N. Y.
New York University, University Heights, New York, N. Y.
North Carolina State College,Raleigh, N. C.
North Carolina, University of, Chapel Hill, N. C.
North Dakota, University of, University Station, Grand Forks, N. D.
Northeastern University, 316 Huntington Ave., Boston 17, Mass.
Notre Dame, University of, Notre Dame, Ind.
Ohio Northern University, Ada, O.
Ohio State University, Columbus, O.
Ohio University, Athens, O.
Oklahoma A. & M. College, Stillwater, Okla.
Oklahoma, University of, Norman, Okla.
Oregon State College, Corvallis, Ore.
Pennsylvania State College, State College, Pa.
Pennsylvania, University of, Philadelphia, Pa.
Pittsburgh, University of, Pittsburgh, Pa.
Princeton University, Princeton, N. J.
Purdue University, Lafayette, Indiana
Rensselaer Polytechnic Institute, Troy, N. Y.
Rhode Island State College, Kingston, R. I.
Rose Polytechnic Institute, Terre Haute, Ind.
Rutgers University, New Brunswick, N. J.
Santa Clara, University of, Santa Clara, Calif.
South Dakota State School of Mines, Rapid City, S. D.
South Dakota, University of, Vermillion, S. D.
Southern California, University of, Los Angeles, Calif.
Stanford University, Stanford University, Calif.
Stevens Institute of Technology, Hoboken, N. J.

Swarthmore College, Swarthmore, Pa.
Syracuse University, Syracuse, N. Y.
Tennessee, University of, Knoxville, Tenn.
Texas, A. & M. College of, College Station, Texas
Texas, University of, Austin, Texas
Utah, University of, Salt Lake City, Utah
Vermont, University of, Burlington, Vt.
Virginia Military Institute, Lexington, Va.
Virginia Polytechnic Institute, Blacksburg, Va.
Virginia, University of, University, Va.
Washington, State College of, Pullman, Wash.
Washington University, St. Louis, Mo.
Washington, University of, Seattle, Wash.
Washington and Lee University, Lexington, Va.
West Virginia University, Morgantown, W. Va.
Wisconsin, University of, Madison, Wis.
Worcester Polytechnic Institute, Worcester, Mass.
Wyoming, University of, Laramie, Wyoming
Yale University, New Haven, Conn.
Total 98

AFFILIATED STUDENT SOCIETY

Brown Engineering Society, Brown University, Providence, R. I.

NOTE: Names of new officers will be printed in the September issue of the JOURNAL. Names of officers serving to July 31 may be found in the July JOURNAL

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(August 1928)

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Motor Bearing Construction.—Bulletin 156, 4 pp. Describes the Wagner improved sleeve bearing and the Wagner ball bearing construction for its motors. Wagner Electric Corporation, 6400 Plymouth Street, St. Louis, Mo.

Motors.—Bulletin 232, 4 pp. Describes Electro-Dynamic "clip-weld," ball bearing, squirrel cage, induction motors, 1½ to 30 hp. A number of new features in mechanical construction are incorporated in this line of motors. Electro Dynamic Company, Bayonne, N. J.

Centrifugal Pumps.—Bulletin 7158, 32 pp. Describes Cameron multi-stage centrifugal pumps designed for modern high pressure boiler feeding, hydraulic service in steel mills, mine drainage, pipe lines, etc. Ingersoll-Rand Company, 11 Broadway, New York.

Arc Welding.—Bulletin GEA-995, 32 pp., "Arc Welding in Industry." Illustrates the application of arc welding to groups of basic operations commonly found in industrial plants. Bulletin GEA-423A, 28 pp., "Arc Welding in G-E Factories." Describes the application of arc welding in G-E manufacturing processes. General Electric Company, Schenectady, N. Y.

Cable Supports.—Bulletin 31-F. Describes a complete line of Delta-Star spool insulator cable supports. The bulletin is entirely thumb indexed by pictures, enabling any desired type or size of support to be quickly located. The Delta-Star Electric Company, 2400 Block Fulton Street, Chicago, Illinois.

Automatic Arc Welding.—Bulletin, 8 pp. Describes automatic arc welding by the "Electronic Tornado" process. This new method of welding is claimed to be a pronounced improvement over past practise, and is the result of a newly discovered method for controlling and localizing the heat of the electric arc. Illustrations showing the application of the new process are contained in the bulletin. The Lincoln Electric Company, Coit Road and Kirby Avenue, Cleveland, Ohio.

NOTES OF THE INDUSTRY

G-E Sales Increase.—General Electric Company sales billed for the first half of 1928 amounted to $158,015,221.41, compared with $149,795,026.99 for the corresponding period last year, President Gerard Swope has announced. Profit available for dividends on common stock for the first half of 1928 was $24,388,002.58 compared with $22,542,972.26 for the corresponding six months last year.

For the six months ending June 30, orders received amounted to $170,357,797, compared with $155,655,828 for the first six months of last year, an increase of 9 per cent.

The Wagner Electric Corporation, St. Louis, Mo., announces that Fred Johnson, heretofore in charge of the St Louis sales office, is now manager of the Los Angeles branch. This transfer brings to a close twenty-one years of service as district manager of the St. Louis territory.

Alex R. Miltenberger, heretofore Pacific coast manager with headquarters in San Francisco, has been transferred to St. Louis as branch manager of that office. Mr. Miltenberger entered the employ of the Wagner Electric Corporation in 1909.

New Ground Wire Clamp.—The Copperweld Steel Company, Glassport, Penn., announces the development of a simple and effective grounding wire clamp. It is designed to encircle the ground rod and securely bind the grounding wire directly to the driven member. No solder or heat is required it merely being necessary to pass the grounding wire into the clamp which has been placed around the driven rod, then tighten by means of a set screw actuated by a set-screw wrench. So securely does this simple little device clamp the wire to the driven member that, it is asserted, the wire is flattened against the rod thus increasing its contact surface and eliminating the possibility of slippage.

New Jersey Power & Light Co. to Build High Pressure Station.—Plans have been announced by W. S. Barstow & Co., Inc., for a new all-1200-lb. station to be built for the New Jersey Power and Light Company at Holland, N. J. The initial installation will consist of a 55,000 kw. turbine generating unit of the cross compound type, comprising a high and low pressure turbine with boiler reheat between them. The high pressure machine will turn at 3600 r. p. m., and will operate directly from the 1200 lb, 725 degrees F mains. The generators of both units will deliver power at 13,800 volts and will have a combined rating of 55,000 kw. An exciter of sufficient capacity to supply both units will be direct connected to the low pressure set.

This station will be the second in the world to be designed entirely for high pressure steam generation. The Deepwater Station, the pioneer all high pressure station, was announced a few months ago. In both stations General Electric turbine generating units will be installed.

G-E Elects Honorary Vice-Presidents.—The office of honorary vice president was created by the directors of the General Electric Company at their meeting on July 6. The board elected to this new office three prominent officials, including J. R. Lovejoy, vice president who has served the company 42 years, George F. Morrison, vice president associated with the company 45 years, and B. G. Tremaine, one of the organizers of the National Lamp Division of the General Electric Company. All three are directors of the company and will continue to function as such, and will retain their association with the several departments of the company's activities with which they have been so closely identified. Their new title is conferred on them in recognition of their long and valuable services to the company.

T. W. Frech, manager of the incandescent lamp department of the company, was elected to the position of vice president in charge of the incandescent lamp department, and Dr. W. R. Whitney, director of the research laboratory, was elected a vice president of the company and director of research.

Detroit Now Has Best Lighted Street.—Washington Boulevard, Detroit, became the best lighted street in the world when on July 10 the new five-light ornamental illumination system was officially placed in service, making the boulevard with its tall buildings on either side a veritable canyon of artificial sunshine.

The lighting standards, placed in double rows along the parkway in the middle of the street, are unique in many respects. According to illuminating engineers of the General Electric Company, who designed the system, they are the most distinctive used anywhere in the country. The illumination per pole, 10,500 candlepower, exceeds State Street, Chicago, heretofore America's best lighted street, by more than 1000 candlepower. The glassware used to house the lamps is also of record-breaking size. This is also the first installation having large Mazda lamps in groups of five to a standard.

The trustees of the Book Estate, visualizing some years ago the development of this wide boulevard into one of the finest retail shopping centers, included in their plans a most comprehensive scheme of lighting—one that would place the boulevard among the finest lightest streets in America.

These tentative lighting plans were turned over to W. D'A. Ryan, director of the illuminating engineering laboratory of the General Electric Company at Schenectady, who with his technical laboratory staff worked out the engineering plans and with J. W. Gosling of the laboratory, the art work in connection with the standards and globes.